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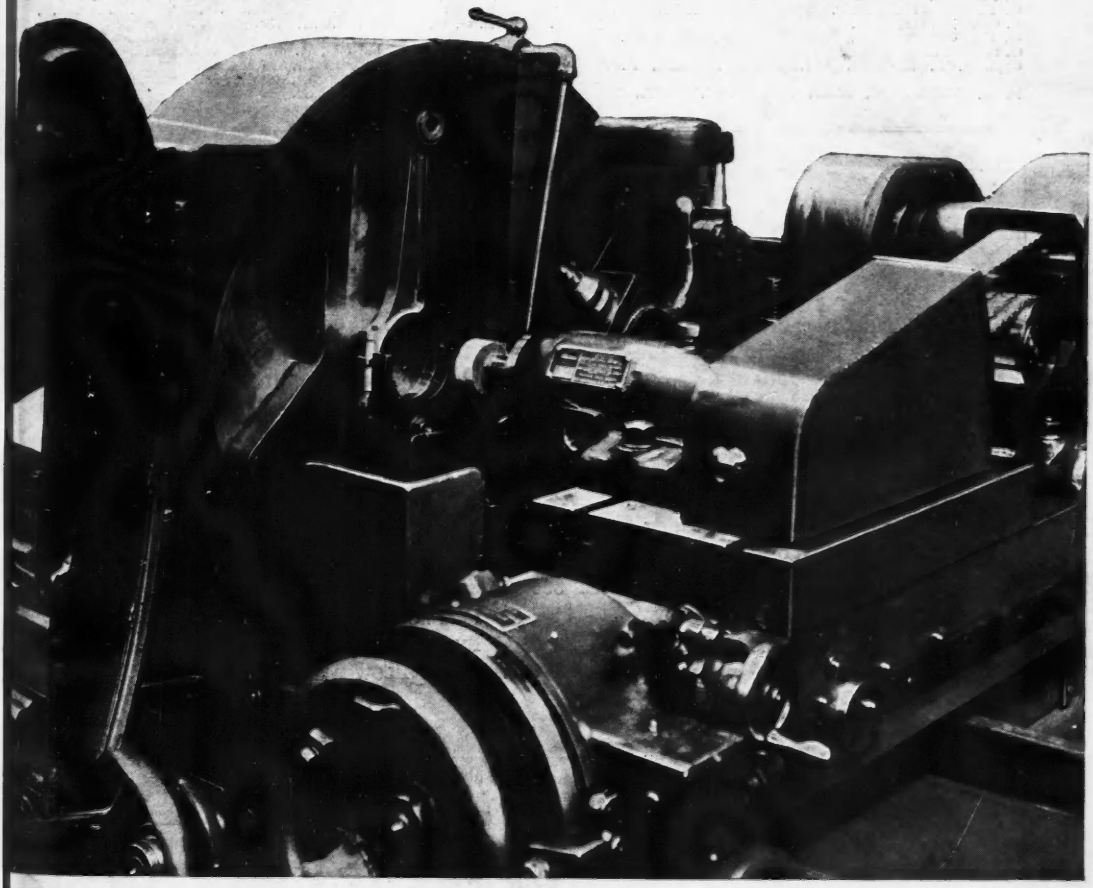

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EDITORIAL

CLEARING HOUSE FOR TECHNICAL INFORMATION.

THE great value of foreign research reports for the collative work which should precede every engineering process has been increasingly recognised in this country in the last few years.

We have been gratified to see, in one recent issue of "Aircraft Engineering" two articles stressing the importance of making available to British Engineers in summarized form all articles, transactions and papers which have appeared in technical periodicals in both friendly and enemy countries.

It has been suggested that there should be some central organization whose business would be to collect and index notes and abstracts on all the subjects of interest to AERONAUTICAL ENGINEERS. *Co-operation of Government Departments, Research Associations and individual firms who already do this work for their own purposes should shorten the time necessary for building up such an organization.*

We hope that if the project of organizing such a clearing house for technical information will be realized, it will be one for all branches of engineering and not merely for aeronautical engineers. Anybody who understands the engineering processes necessary for the building of a hydroelectric work, or an aeroplane, a locomotive, or even the manufacture of a simple screw, will realise the correlation of the many specialized branches of engineering science.

It would be of the greatest benefit to the British Engineering World if the plan of such a clearing house for technical information could be carried into effect as soon as possible.

There are many organizations in this country suitable to deal with this task. A co-operative effort between the D.S.I.R., The Science Museum, The Patent Office Library, and the four main engineering organizations the "Civils," "Mechanicals," "Electricals" and the "Iron and Steel Institute" would be, no doubt, worth while to consider.

* * * * *

AN APOLOGY.

OWING to limitation of paper we are compelled to print a considerable proportion of our journal on uncoated paper. We wish to apologize and ask for the kind understanding of those of our Readers who will receive from now on our journal printed on that thinner paper. It will be our endeavour to make up for this deficiency of paper by special attention to the printing of illustrations.

* * * * *

SCHOOL OF INDUSTRIAL AND ENGINEERING RADIOGRAPHY.

THE Directors of Kodak Ltd. have made a most generous contribution towards engineering science by establishing a School of Industrial and Engineering Radiography. The importance of radiological examination is well proved by the great use the M.A.P. is making of it, and by the increasing application of X-ray in the Metallurgy and in other engineering industries.

The inauguration of the school took place on the 6th of January. Dr. V. E. Pullin, C.B.E., representing the M.A.P., has stressed in his introductory speech how radiological inspection, to which some 300,000 aircraft castings are subjected every month, has contributed to building up the magnificent morale which characterize the R.A.F.

The opening speech was made by Professor E. N. da C. Andrade, F.R.S., the distinguished physicist who mentioned the importance of the X-ray method of examining engineering materials, characterizing it with the single word "welds." He remembered how Dr. Pullin had started some 25 years ago at Woolwich with a little apparatus, to build up a laboratory for the X-ray examination of mechanism and materials, and how he succeeded in building out of not very promising material an institution which in some years had become known to all progressive engineers in this country and in most other lands.

Mr. W. G. Bent, Deputy Chairman of Kodak Ltd., expressed the wish that X-ray may benefit Industry to the same extent as it has been serving humanity in its medical applications.

* * * * *

L. KALLIR.

WE very much regret to have to announce the loss of a dear friend and faithful collaborator of our journal, Mr. L. KALLIR, who died recently at the age of 68.

Mr. Kallir whom we greatly admired for his kindness and appreciated for his great knowledge and straightforward character, has worked for the DIGEST *since its commencement and was responsible for a great number of abstracts on electrical subjects. He was also employed, for the last two years, with The British Electrical and Allied Industries Research Association.*

In the years 1896-1900 *Mr. Kallir was Assistant Professor for Electrical Engineering on the Vienna Technical University. For* 38 *years* (1900-1938) *he was associated with the A.E.G. Union Electrical Company in Vienna, at first as an engineer, and since* 1908 *as a Director of the Company. In that latter capacity he was responsible for the construction of a number of Power Plants, Transformer Stations, High Tension Lines, Distribution Systems, and, after* 1930, *for the Electrification of the Austrian Railways.*

Many papers by Mr. Kallir have been published in foremost electrical engineering journals in different countries.

Mr. Kallir was President of the Electrotechnical Society in Vienna in 1928-30, *Chairman of the Electrotechnical Commission of the I.E.C., London, in* 1926-38, *and had many honorary functions in acknowledgment of his work devoted to public interests.*

J. E. PAJZS.

CODE FOR WORKING STRESSES

By JOSEPH MARIN, Pennsylvania State College. (From *Machine Design*, Vol. 14, No. 11, November, 1942, pp. 70-74 and 158-160).

PART I.—STATIC STRESSES.

MODERN developments in machine design are requiring a more rational estimate of design factors such as magnitude and character of loads acting on the part and properties of the material used.

The important consideration of weight reduction in aircraft and many other constructions demands a more accurate determination of dimensions.

The influence of service and operational requirements on the size of parts may sometimes be the governing consideration, while strength becomes a minor factor. On the other hand, loads and material properties may often be controlling factors.

Accuracy of stress determination is governed by the accuracy of the load and reliability of the stress analysis used. Precise load determination and stress analysis lead to a reduction in the factor of safety used and, hence, to a safer and more economical construction.

Selection of material also has become increasingly important. The required properties may include resistance to wear, corrosion or fatigue and high temperatures.

Quantitatively, the mechanical properties of a material determine the size of a member. Therefore stiffness, ductility, resilience, or strength may decide the dimensions selected. The governing mechanical property in many machine parts being strength, this article will be confined to working stresses based on the strength of materials. The working stress is

$$S_w = \frac{S}{N} \quad .. \quad .. \quad .. \quad (1)$$

S_w is equal to the failing stress S divided by the factor of safety N. In order to design both economically and safely, the strength S and the factor of safety N must be evaluated as closely as possible.

Selection of Factor of Safety.

Past performance of a machine part plays an important role in the selection of the factor of safety N. For the purpose of a rational determination of N, a separation of the various factors influencing it is desirable. If $N_1, N_2, N_3, \ldots . N_n$ denote the quantitative value of each factor, then the overall factor of safety can be expressed by

$$N = N_1 \times N_2 \times N_3 \ldots \times N_n \quad (2)$$

These factors are :

1. Material Factors N_1, N_2 and N_3 : they consider the possible variation in the strength S as well as the differences between the laboratory test on which S is based, and the service conditions. The possible non-uniformity in strength due to manufacture and inaccuracy of testing can be approximately predicted and an allowance for the factor of safety can be estimated. If the expected variation in strength is $k_v S$, the material factor N_1 is

$$N_1 = \frac{S + k_v S}{S} = 1 + k_v \quad .. \quad .. \quad (a)$$

The material factor N_2, which allows for the difference in behaviour between the laboratory strength and the strength in the prototype, is a difficult one to estimate. If the strength S considers the type of load and the " combined stress effect," the factor N_2 may be modified. In machine design the weakest point in the member is considered, and adjacent parts are not stressed to their maximum possible values. With ductile materials and static loads this condition prevents failure in many cases. For example, the yielding at a rivet hole under static conditions is not serious since a redistribution of stress with increase in stress values at the lower stressed points, and descrease in stress at the higher stressed points, is produced. If stress concentration is not considered in determining the strength an allowance must be made for this. If the foregoing considerations are provided for by the factor k_c the material factor N_2 is

$$N_2 = \frac{S + k_c S}{S} = 1 + k_c \quad .. \quad .. \quad (b)$$

A third material factor N_3 is applicable to static loads and ductile materials only. This value attempts to provide for the variation in the ratio of the yield tensile strength S_{yp} to the ultimate tensile strength S_u of ductile materials. An approximate method which allows for this is to introduce the factor N_3 as given by the equation

$$N_3 = \frac{S_{yp} - (S_u - S_{yp})}{S_{yp}} = 2 - k_u \quad .. \quad (c)$$

where $k_u = S_u / S_{yp}$.

2. Load Factor N_4 : The actual load on a member will not be that assumed in design, since the magnitude, distribution and type of loading can usually be only roughly approximated. In many cases an estimate can be made of the possible load variation from that assumed. When impact loads are present an equivalent static load can be determined. Stress variations corresponding to the possible load variations can be estimated, and if this stress variation is $k_2 S_w$ the factor N_4 is

$$N_4 = \frac{S_w + k_2 S_w}{S_w} = 1 + k_1 \quad .. \quad .. \quad (d)$$

3. Stress Analysis Factor N_5 : Many problems arise in design for which the stress analysis is inadequate. Even under conditions where static loads and Hooke's law can be assumed, the theory of elasticity has its limitations and an approximate stress value is determined. When conditions of vibration or instability occur, an improved method of stress analysis should be used. The photoelastic, strain rosette, and stress-coat methods have been of great help in this respect[1]. In a particular design, if the percentage error in stress, based on experimental or improved theoretical method, is $100\ k_a$, the stress analysis factor becomes

$$N_5 = \frac{S + k_a S}{S} = 1 + k_a \quad .. \quad .. \quad (e)$$

4. Fabrication Factor N_6 : Generally, for machine parts the actual dimensions are not those assumed in determining the stress. The error can be taken care of by selecting an appropriate fabrication factor. More important than variations in dimensions are the changes in the properties of the material and the initial stresses sometimes produced by the method of fabrication adopted. Riveting, bending, hammering introduce initial stresses ; sometimes the heat treatment applied has a variable effect. Often these influences can be estimated with reasonable accuracy. If the fabrication factor is k_f, the fabrication factor of safety becomes

$$N_6 = \frac{S_w + k_f S_w}{S_w} = 1 + k_f \quad .. \quad .. \quad (f)$$

(1) All references are listed at the end of the article.

5. Time Factor N_7 : This factor includes the influence of external conditions in modifying the material properties (e.g., corrosion of steel or decay of wood by moisture). Another time factor which is sometimes provided for in the determination of S is the influence of creep (which is a continued plastic deformation with time) at both normal and elevated temperatures. Creep has an important influence on the selection of working stresses. Many studies have been made on parts which have been in operation for a number of years. Laboratory tests have been useful in some problems in estimating the influence of time effects on strength. Based on the foregoing consideration, a time factor N_7 will be selected in terms of the correction factor k_t where

$$N_7 = \frac{S + k_t S}{S} = 1 + k_t \quad .. \quad .. \quad (g)$$

6. Failure Factor N_8 : In determining the factor of safety, the consequences in the event of failure are an extremely important consideration. If failure would result in loss of life or in loss of valuable property or serious interruption of production processes, an ample factor of safety should be provided. Sometimes certain precautions can be taken to eliminated serious consequences if failure occurs. Spiral-steel reinforcement in concrete columns is an example of this kind of insurance against a disastrous type of failure. For ductile materials and static loads, yielding accompanied by redistribution of stresses also gives an insurance against serious failure.

It will be necessary to determine the failure factor of safety N_8 from information available on previous failures and from experience with similar constructions. Thus,

$$N_8 = \frac{S_w + k_e S_w}{S_w} 1 + k_e \quad .. \quad .. \quad (h)$$

The resultant factor of safety becomes

$$N = N_1 \times N_2 \times N_3 \times N_4 \times N_5 \times N_6 \times N_7 \times N_8 \; .. \quad (2a)$$

Substituting equations (a) to (h) in equation (2a),

$$N = \frac{(1+k_v)\,(1+k_c)\,(2-k_u)\,(1+k_l)}{(1+k_a)\,(1+k_f)\,(1+k_t)\,(1+k_e)} \quad .. \quad (3)$$

where k_v = material variation factor
k_c = material stress factor
k_u = ratio of ultimate strength to yield strength in static tension
k_l = load variation factor
k_a = stress analysis factor
k_f = fabrication factor
k_t = time factor
k_e = failure factor.

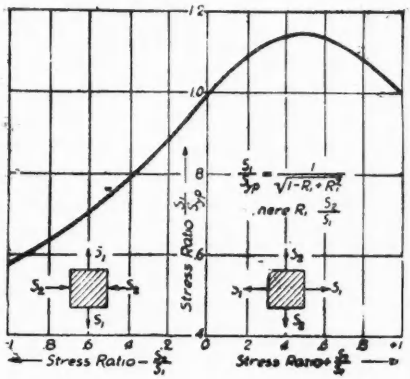

Fig. 1. Strength ratio for ductile materials and biaxial stresses for the stresses shown in the sketches.

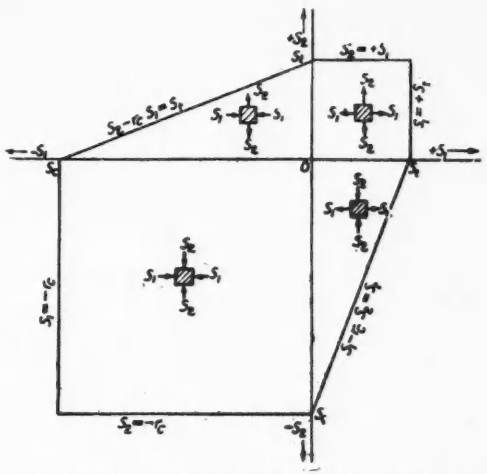

Fig. 2. Theory of failure for brittle materials and biaxial stresses. Stresses are shown in each quadrant.

Separation of the many considerations influencing the factor of safety has been made in a simple manner so that a more intelligent estimate of each can be provided. The other quantity which must also be known before the working stress can be determined is the strength of the material deignated by S in equation (1). This strength will be the yield strength for ductile materials or the ultimate strength in the case of brittle materials, both subject to static loads. For fluctuating stress conditions the strength is dependent on the fatigue stress. The stress S is then defined as an equivalent static tensile stress. For problems in which a combined state of stress occurs an equivalent simple static stress S can be obtained for either static and fatigue stresses. Another consideration that will be incorporated is an allowance for stress concentration. The discussion will be confined to static and fatigue stresses only.

Development of the theories of failure used in the following will be omitted, with only references being given as to where the development of the theory can be found[2]. For the purpose of defining strength, materials will be classified into two groups : *Ductile materials* having an elongation in simple tension of more than 5%, and *brittle materials* having an elongation of less than 5%[3]. The strength of ductile materials will be defined by the yield strength S_{yp} based on the lower yield point where one exists or on the A.S.T.M. offset yield strength[4] where a pronounced yield does not exist. For many ductile materials the yield strengths in tension and compression can be assumed equal. On the other hand, for brittle materials the strength must be defined by the ultimate strength and the values of the strength in tension and compression may be appreciably different.

Uniaxial Stresses—Ductile Materials : Strength in compression can usually be assumed equal to that in tension. The strength is based on the yield strength S_{yp}, as previously explained. That is $S = \pm S_{yp}$ (4)

Uniaxial Stresses—Brittle Materials : For materials with an elongation less than 5%, the ultimate stress defines the strength. If the ultimate strength in tension is S_t and in compression S_c, the strengths are, respectively,

$$S = +K_t S_t \text{ and } S = -K_c S_c \quad .. \quad (5)$$

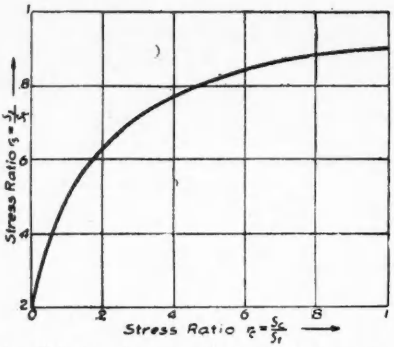

Fig. 3. Relation between shear strength and compressive strength ratios.

where K_t and K_c are stress concentration factors in tension and compression respectively. Values of stress concentration factors for some types of fillets and certain simple stress problems have been obtained and are compiled by Roark[5].

Biaxial Stresses—Ductile Materials: For ductile materials subject to biaxial principal stresses S_1 and S_2, failure will be defined by the distortion-energy theory. Many designers still use the shear theory and argue that this is easier to apply. Since the experimental evidence definitely favours the distortion-energy theory for biaxial stresses it seems to the writer that this theory should be used. The relation between the principal stresses S_1 and S_2 by the distortion-energy theory is

$$S_{yp}^2 = S_1^2 - S_1 S_2 + S_2^2 \quad .. \quad .. \quad (6)$$

To represent the influence of the combined stresses, considering that S_1 is the greatest principal stress, Equation 6 becomes

$$\frac{S_1}{S_{yp}} = \pm \frac{1}{\sqrt{1 - R_1 + R_1^2}} \quad .. \quad .. \quad (6a)$$

where $R_1 = S_2/S_1$ and $S_2 < S_1$.

Variation in the stress ratio S_1/S_{yp} with the change in the stress ratio $R_1 = S_2/S_1$ is shown in Fig. 1. This figure can be used now to select the equivalent strength S_1 for any stress ratio R_1.

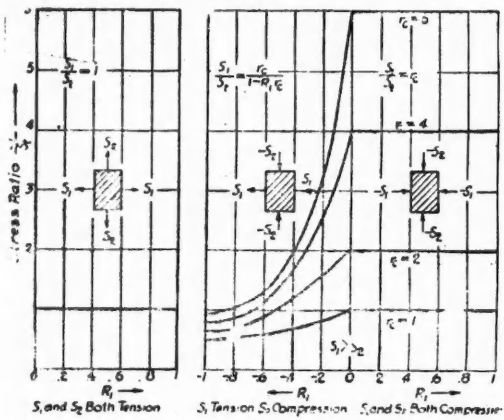

Fig. 4. Strength for brittle materials and biaxial stresses.

If the stress components are expressed in terms of the normals stress S_x and S_y and a shear stress S_{xy} in place of the principal stresses S_1 and S_2, Equation 6 then becomes

$$S_{yp}^2 = S_x^2 - S_x S_y + S_y^2 + 3 S_{xy}^2 \quad .. \quad (6b)$$

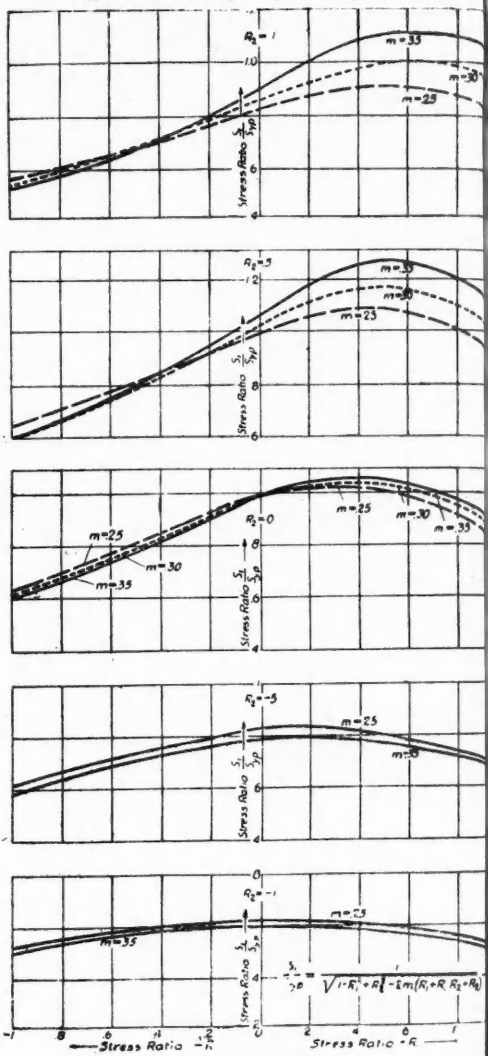

Fig. 5. Strength ratios for ductile materials and triaxial stresses for various values of R_2.

Biaxial Stresses—Brittle Materials: For brittle materials such as cast iron, which are subject to biaxial stresses, there is little experimental data upon which to base strength values. It is highly desirable to provide at least for the difference which exists between the tensile and compressive strengths of most brittle materials. For this purpose the internal friction theory or a special case of Mohr's theory is recommended[2]. This theory

is defined by the following equations where $S_1 > S_2$ and is represented graphically in Fig. 2.

For principal stresses of the same sign,

$$S_1 = -S_c \text{ or } S_1 = S_t \quad .. \quad .. \quad (7a)$$

For principal stresses of opposite signs,

$$S_1 - r_c S_2 = S_c \quad .. \quad .. \quad (7b)$$

where $r_c = S_c/S_t$.

For the case of pure torsion, Equation 7b can be used by placing $S_1 = -S_2 = S_s$, where S_s is the shear strength in torsion. Then

$$r_s = \frac{r_c}{1+r_c} \quad .. \quad .. \quad .. \quad (i)$$

where $r_s = S_s/S_t$ and $r_c = S_c/S_t$.

The variation in r_s with change in the values of r_c, as required by Equation i, is shown in Fig. 3. Tests on thin-walled cast iron tubes in torsion indicate that this theory gives a reasonable approximation with results on the safe side of the test values. The test point in Fig. 3 represents values obtained by Draffin and Collins[6].

If stress concentration, Equation 7 can be written

$$\left.\begin{aligned} K_1 S_1 &= -S_c, \; K_1 S_1 = S_t \\ K_1 S_1 &- r_c K_2 S_2 = S_c \end{aligned}\right\} \quad .. \quad .. \quad (8)$$

To represent the combined stress effect it is desirable to write Equation 7 in terms of the stress ratios $R_1 = S_2/S_1$ and $r_c = S_c/S_t$, that is,

$$\left.\begin{aligned} \frac{S_1}{S_t} &= r_c, \quad \frac{S_1}{S_t} = 1 \\ \frac{S_1}{S_t} &= \frac{r_c}{1 - r_c R_1} \end{aligned}\right\} \quad .. \quad .. \quad (9)$$

Equations 9 are shown plotted in Fig. 4 for various values of the stress ratio r_c. The equivalent strength S_1 can be selected direct from Fig. 4 for any stress ratio R_1.

Triaxial Stresses—Ductile Materials: For ductile materials subject to triaxial stresses S_1, S_2, and S_3, there are no conclusive experiments available. For this reason it is desirable to be cautious and to use a conservative theory. Under certain combinations of stress the distortion-energy theory gives unreasonably high strength values. Therefore, the more conservative strain-energy theory is recommended. This theory has also the desirable feature that it agrees closely with the distortion-energy theory in the case of two-dimensional stresses. By the strain-energy theory the strength relation is

$$S_{yp}^2 = S_1^2 + S_2^2 + S_3^2 - 2m(S_1 S_2 + S_2 S_3 + S_1 S_3) \quad (10)$$

where m Poisson's ratio. To represent the combined stress effect, Equation 10 can be represented in terms of the stress ratios R_1 and R_2 as follows:

$$\frac{S_1}{S_{yp}} = \frac{1}{\sqrt{1 + R_1^2 + R_2^2 - 2m(R_1 + R_1 R_2 + R_2)}} \quad (11)$$

where $R_1 = S_2/S_1$ and $R_2 = S_3/S_1$.

Equation 11 is plotted in Fig. 5 for various values of Poisson's ratio. In this way the strength S_1 can be selected for any given stress ratios R_1 and R_2.

When the stress components are not principal stress values but normal stresses S_x, S_y, S_z and shear stresses S_{xy}, S_{yz}, S_{xz}, the relation between the stresses is given in the following:

$$S_{yp}^2 = S_x^2 + S_y^2 - 2m(S_x S_y + S_y S_z + S_z S_x) - 2(1+m)(S_{xy}^2 + S_{yz}^2 + S_{zx}^2) \quad .. \quad .. \quad (12)$$

Triaxial Stresses—Brittle Materials: The internal friction theory can be used for three-dimensional stresses S_1, S_2, and S_3 provided the stresses S_1 and S_2 are selected as the maximum and minimum principal stress values respectively. Equations 7, 8 and 9 can then be used for triaxial stresses and brittle materials. Figs. 1, 2, 3 and 4 represent the equivalent strength ratios S_1/S_{yp} or S_1/S_t for different materials and stress combinations. These diagrams also show the influence of the combined stress on the equivalent simple tensile strength since simple tension is represented by an ordinate equal to one. The value of S_1 thus obtained can now be substituted for S in Equation 1 to obtain the working stress S_w.

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INVESTIGATIONS OF WATER TURBINE REGULATORS

By HANS GERBER, Escher Wyss A.G., Zurich. (From *Schweizerishe Bauzeitung*, Vol. 120, No. 2, 11th July, 1942, pp. 13-16

IN designing the governing and regulating apparatus of water turbines one should aim at a minimum governing work and the most uniform distribution of forces over the whole governing range. To achieve this an exact knowledge of the distribution of the hydraulic forces under all operating conditions is required. These questions have been solved by means of experiments performed on models and on actually existing plants, both for the needle and deflector of impulse turbines, and for the runner and guide vanes of Kaplan and Francis turbines. The experimental methods used and the characteristics obtained are described.

Governors of water turbines serve two purposes: (a) To obtain quickly and safely a setting at any load, keeping speed and pressure fluctuations within a close range, (b) to conduct the hydraulic energy to the runner in such a way that the best possible transformation into mechanical energy is obtained.

As it is impossible to achieve both these requirements taking account of both construction and cost, it is necessary to choose the construction of the governing parts so that a minimum work is required for their operation. This results in small servo-motors and small oil pumps, thus reducing the cost of manufacture. Smaller sizes of servo-motors also result in small displacement forces, thus with the same size of valves and pipe lines shorter regulating times are obtained.

In the construction of water turbines, therefore, various points have to be considered. Safety considerations have to be borne in mind especially, as many plants are only occasionally attended or not attended at all.

Exact knowledge of the size and the distribution of the hydraulic and mechanical forces is essential. Besides theoretical and constructive studies there are two other possible lines of investigation of the conditions in the

governing apparatus: (a) experiments on models, (b) measurements on existing plants.

The magnitude and direction of the hydraulic forces are mainly determined by experiments performed on models. Measurements performed on actual plants give the total occurring forces, which normally consist of hydraulic and friction forces. Both methods complete each other and should be used in conjunction.

For the measurements on turbines a simple and movable arrangement is required, which allows the time of an experiment to be shortened as much as possible. Fig. 1 shows such an arrangement consisting of two coupled indicators with exchangable springs mounted on a common base. For instantaneous readings pressure gauges are put in parallel with each indicator. Each indicator can be connected to one side of the servo-motor which is to be tested. The indicators are operated by the servo-motors through a stroke adjustment mechanism. In this way the regulating pressure is indicated on a proper stroke base. This arrangement enables one to determine the size and distribution of all the forces of interest in estimating the work required for the governing of water turbines. A summary of the characteristic conditions of the regulating apparatus used in water turbines to-day is given below.

Needle of Impulse Turbine Regulator.

The needle regulators of to-day give in all practically possible positions of the needle a round compact jet. Fig. 2 shows a section through such a regulator, the needle being in the open position.

The following formula applies for the hydraulic closing force acting on the needle.

$$P = \frac{\pi}{4} p (K D^2 - d^2) \qquad (1)$$

Where p = static pressure at entry.
D = Diameter of nozzle opening
d = Diameter of needle guide.

When the needle is closed, $P = \frac{\pi}{4} (D^2 - d^2)\ p$ is the total pressure on the annulus area which can easily be calculated, i.e., K = 1. In the open position a considerable part of the static pressure is turned into velocity near the tip of the needle. In this position the closing force is decreased, which is being taken into

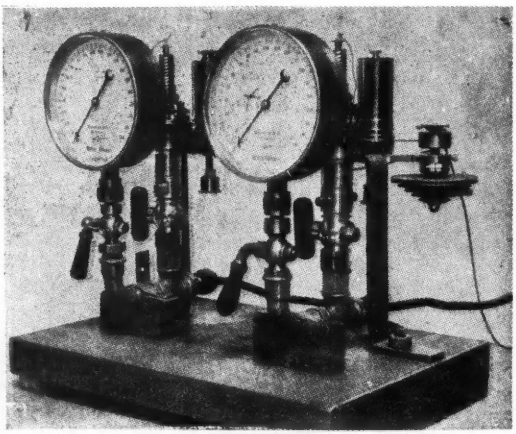


Fig. 1.

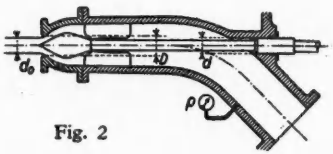


Fig. 2

account by the coefficient K (<1); the values of this coefficient have been found experimentally on the model; a graph obtained by plotting K against the lift of the needle is shown in Fig. 3. It is obvious from formula (1) that by the choice of the diameter d, any size and direction of the force P can be chosen. The smallest regulating force is obtained, if the closing force with the needle in the closed position is equal and opposite to the force with the needle in the open position. This solution is only desirable, if a regulating pressure is definitely always available, as, e.g., in regulating systems with air vessels or water pressure. If this regulating pressure was not available, the needle would open automatically in the case of larger needle strokes.

The diameter d, therefore, is usually chosen in such a way as to make the needle close of its own accord when it is in the fully open position, a certain excess of closing force being required to overcome the mechanical resistance. This solution implies a considerable opening force when the needle is in the closed position.

This difficulty can be avoided in the case of small and medium-sized plants by means of a closing spring, the characteristic of which follows approximately the hydraulic opening force.

In this case d is chosen so that d = D. Then according to (1) the hydraulic opening force is propor-

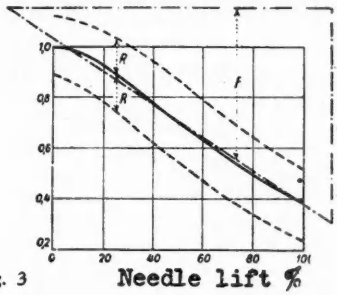


Fig. 3

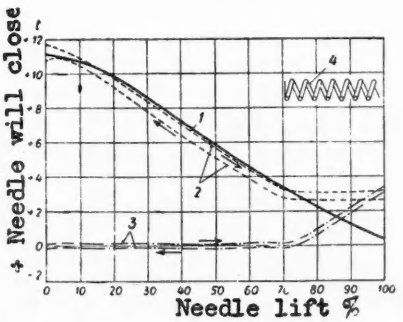


Fig. 4

(1) Theoretical force on needle, (2) Opening and closing force with water pressure, (3) without water pressure, (4) closing spring $^2/_3$ opened.

tional to 1-k, thus being zero when the valve is closed. The spring F (Fig. 3) has at this point an excess of closing force which safely overcomes the friction R. Theoretically, therefore, the force 2R is required for opening, and it is constant for the whole needle lift. Though the required spring becomes impracticably large in the case of larger machines, the regulating force can be considerably reduced by applying the above principle of spring control to minimise the maximum effort when larger needle strokes are used. Fig. 4 shows the results of the measurements performed on a 20,000 H.P.-turbine, to which this solution has been applied; the agreement with experiments obtained on models is satisfactory.

Jet Deflector in Impulse Turbines.

The deflector controls the adjustment of water quantities to the runner for any decrease in load without causing pressure hammer effects in the pipe line. As the closing times are usually one second or less, the moving masses and the size of the servo-motors have to be reduced to a minimum.

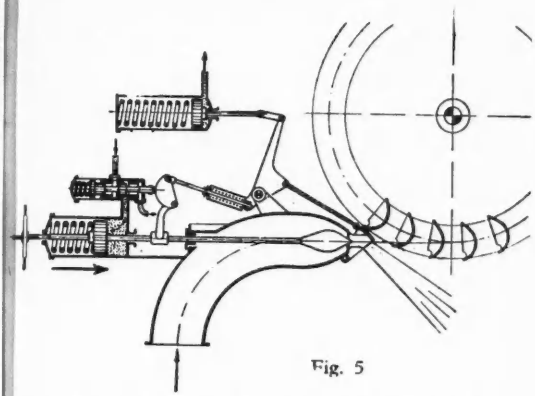


Fig. 5

Fig. 5 and 6 shows the arrangement of the jet deflector. It is pressed against the jet from the side of the wheel and influences the whole jet from the moment of contact. This results in a smaller movement of the deflector for a given deflection of the jet. Thus the jet deflector has to be moved only about 40% of the full jet diameter, in order to deflect the jet by 30%, when the needle is in the open position.

A jet deflector works the better, the more completely it deflects and dissipates the jet when submerged at a certain depth, thus destroying its energy (Fig. 7).

The considerable sensitivity of size and direction of the hydraulic forces and their dependence on the shape

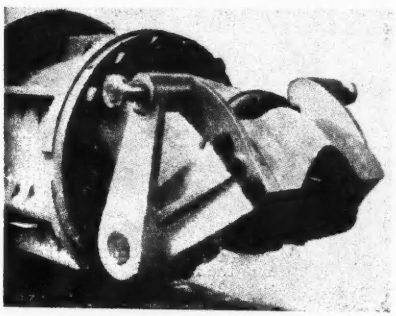


Fig. 6

Fig. 7. Jet deflected through 15%; Needle lift=20%.

variations of the deflector can be concluded from the dissipation of jets shown on indicator diagrams obtained from actual plants. Fig. 8 shows the characteristic curves of a large turbine, both for the closed and open needle position. The position is expressed as a percentage of the maximum distance between the axis of the jet and edge of the deflector. Curve (4) shows that the deflector is initially pulled into the jet, but from 50 per cent upwards it has to be pressed into the jet. The zero load had been reached in this case in the 13% position. The force distribution shows that, due to the small vibrations occurring with the deflector dipping in deeply, the friction completely disappears, while it changes only slightly with the needle in the closed position.

The relation of turning moment and deflecting angle of a model jet deflector are shown in Fig. 9. The results of Fig. 8 have been confirmed qualitatively, not, however, numerically, and extensive experiments on further models (Fig. 10) prove the sensitivity of examined shapes to small differences in design and workshop inaccuracies. Due to extensive experiments on models it was found possible to reduce considerably the hydraulic turning moment by choosing the proper shape and the corresponding centre of rotation and especially, to obtain a stable characteristic. It has also been found out, how regulating forces alter, when the deflector becomes damaged and rough during its use, or when there are differences from the original drawing due to inaccurate machining.

Kaplan Turbine Runners.

With the increase of the specific speed and the water absorption capacity, and the large increase of the di-

Torque of the deflector against deflector position. (1) Opening and closing motion when needle open; (2) When needle closed; (3) Begin of dipping-in; (4) Hydraulic force; (5) Load=0.

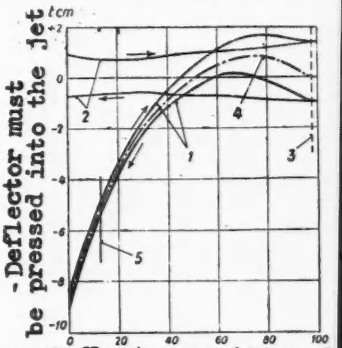


Fig. 8

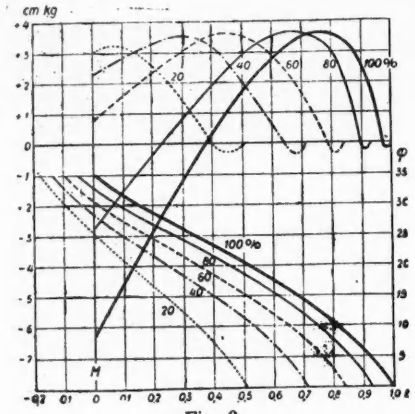


Fig. 9

Top (left) : torque, Bottom (right) : Jet deflecting angle of a model jet deflector plotted against the distance between the edge of the deflector and the jet axis.

mensions and the use of rotating hydraulic servo-motors the necessity arose to determine the forces required to rotate the blades of the runner.

The forces acting on the blades in circumferential and axial direction can be determined with satisfactory accuracy by applying the principles of aerofoils. Experiments on actual plants, however, were required to determine the frictional forces of the packings, journal bearings of the blades, and regulating mechanism. For this purpose the apparatus described above was used. Fig. 12 shows diagrammatically the regulation of a runner with a servo-motor built into the shaft. The oil pressures are being measured in the oil pressure connecting housing above the exciter. For slow regulating movements the pressure losses in the oil ducts between the oil inlet and the servo-motor are negligible. The measurements were performed under the following conditions : (a) With guiding cam, i.e., with the guide vane ring connected automatically to the runner as under working conditions ; (b) Without guiding cam, i.e., at different fixed positions of the guide vanes.

Fig. 13 represents two characteristic curves with the guide vanes being blocked in the maximum open position : (1), (2) and (3) represent a low pressure runner with four short blades of large twist ; (4), (5) and (6) represent a high pressure runner with six long blades of small twist. The friction is approximately constant over the whole range of swivel. On the other hand, the course of the hydraulic torque is different with each runner. It seems to be more uniform, the greater the relative displacement of the different cylinder sections. The position of the curves (3) and (6) relative to the origin depends not only on the position of the centre of rotation of the blade profile, but also on the specific

Fig. 10. Examined jet deflectors.

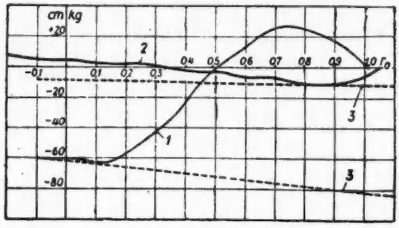


Fig. 11

Comparison of the hydraulic characteristics of the old and new deflector with fully open needle valve. Torque plotted against distance from axis. (— means " deflector must be pressed into jet "). (1) Old type ; (2) New type ; (3) Characteristic of governor with closing spring.

speed. The larger the speed of a definite turbine, the larger will be the hydraulic turning moment about the blade axis in the opening sense. It is, therefore, hardly possible to make a blading which is balanced under all operating conditions.

It is interesting to note that the American firm, Newport News, have designed a self-governed Kaplan turbine runner. The idea is definitely attractive but there appear to be difficulties in construction and operation, so that it seems to have hardly any advantages over the usual approved oil pressure governing.

Guide Vanes of Kaplan and Francis Turbines.

With the introduction of Fink's pivoted guide vane the question arose as to what force was required to

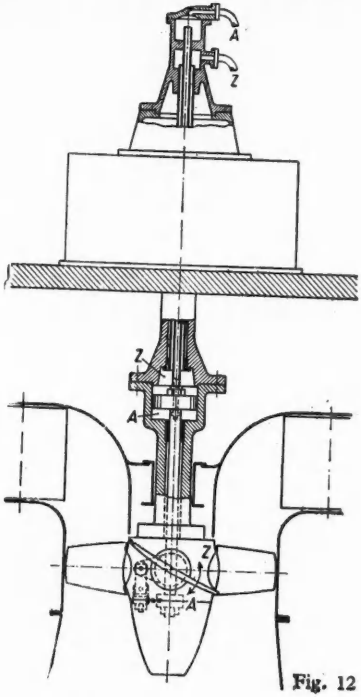


Fig. 12

(A) Oil inlet underneath the piston for opening the runner ; (Z) Oil inlet for closing the runner.

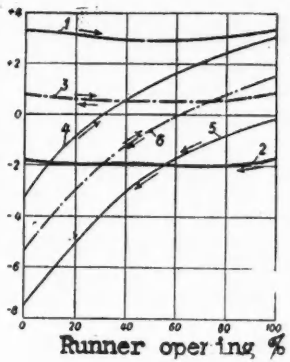


Fig. 13

t+ = Runner will close; (1) and (4) Opening movement; (2) and (5) Closing movement; (3) and (6) Hydraulic force.

regulate it. For Francis turbines useful information can be obtained from tests made by Dr. A. Strickler. He found that the work required for the regulating of the guide vanes of turbine does not only depend on the shape and number of vanes, but also on the type of water admission used (open chamber, spiral chamber).

It is assumed in the following examinations that the guide vane mechanism employed was correct as far as the shape and number of vanes are concerned, so that the considerations of turbine efficiency is unnecessary.

With Francis turbines the aim of the designer is to equalise, if possible, the maximum opening force and the maximum closing force; the sum of both, however, should be as small as possible. Fig. 14 shows the measurements obtained on two vertical high pressure Francis spiral turbines. The character of the curves is different. In one of the plants it was possible to make the maximum opening and closing forces balance, the friction, however, was constant over the whole regulating range and considerably large. The other guide vane arrangement is hydraulically very badly balanced. The friction losses, however, are considerably smaller, and reach a maximum when the hydraulic torque reaches its maximum value.

The conditions are different in modern Kaplan and propeller turbines, where the pressure between the guide vanes and the runner is lower than it is in Francis turbines.

Indicator results obtained from the servo-motor operating the guide vanes of a 10,000 PS high pressure Kaplan turbine are given for the two extreme runner positions in Fig. 15. With closed runner (curves 1, 2, 3)

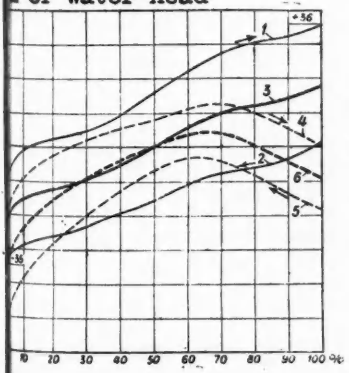


Fig. 14

Regulating force of servo-motor against runner-opening in % taken from two high pressure Francis Spiral turbines.

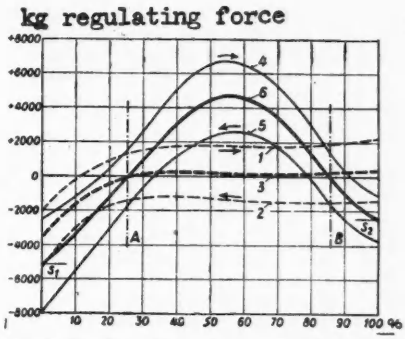


Fig. 15

the closing force has only one maximum value at 0% stroke of the servo-motor. With open runner (curves 4, 5, 6), however, there is a smaller peak at 100% stroke of the servo-motor, besides the maximum closing force at 0% stroke mentioned above; further between 50 and 60% stroke a maximum opening force of approximately the same size as the closing force at 0% stroke is obtained In the positions A and B, called "floating points," the hydraulic torque is zero; the guide vanes, therefore, when the regulating force is absent, will tend to take up one of the positions under the influence of the flow. It is desirable that the runaway speed of the turbine, when in the smaller floating position A, should be below the speed at no load. The governing of the tested turbine was obviously mechanically in order, as the friction torque was small compared with the hydraulic torque. Indications like these prove the correctness of the guide vane governing arrangement and the quality of the mounting. In large plants it is customary to take indicator readings periodically in order to detect faults in the bearings, dirt particles, etc. To obtain the probable hydraulic curve from the opening and closing

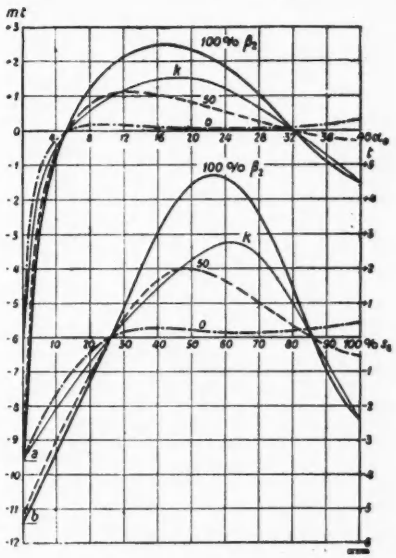


Fig. 16 (Left): Torque in mt (— = guide vanes will open); (Right): Regulating force in t (— = servo-motor must close); (Top): Swivel angle α_o of guide vane in degrees; (Bottom): Servo-motor stroke S_o in %

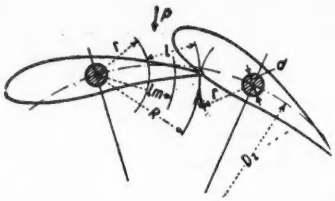


Fig. 17

curves one can assume, that at a given position of the governing mechanism the friction force is equal in both directions of motion. Thus a diagram as shown in the lower part of Fig. 16 is obtained for the hydraulic governing force of the guide vane servo-motor of a Kaplan turbine for different runner positions β_2. By taking the design of the connecting mechanism into account it is possible to calculate the moment about the axis of the guide vanes (Fig. 16 top). By the use of suitably connected levers the larger peak of the closing force can almost be reduced to the value of the maximum opening force.

Under normal operating conditions there is a definite runner vane position corresponding to each guide vane opening if a maximum efficiency is to be obtained. It can be seen from the Kaplan governing curve K (Fig. 16), that under normal operating conditions the maximum opening force is considerably lowered compared with the operating condition of a propeller turbine with a runner position $\beta_2 = 100\%$ At the runaway speed of the Kaplan turbine the conditions can become even worse than for propeller turbines as the back pressure resulting from the runner is in this case considerably less. The floating points are obviously independent of the runner vane position.

There have been frequent attempts to represent the regulating work of guide vanes by means of mathematical formulae. This appears to be simplest in the closed position (Fig. 17), as there is a resulting static turning moment about the pivot of the guide vane. The following expression can be obtained for the hydraulic torque in the opening sense.

$$M_h = z_o \, p \, B_o \, l \, l \, m \quad .. \quad .. \quad (2)$$

this can be transformed to :

$$M_h = \frac{z_o \, B_o \, p}{2} (R^2 - r^2) \quad .. \quad .. \quad (3)$$

The friction torque equals

$$M_r = K \, \mu \, p \, B_o D_z \, d \quad .. \quad .. \quad (4)$$

where z_o = number of guide vanes
D_z = guide vane pivot circle diameter
d = guide vane pivot diameter
B_o = width of guide vane ring
p = water pressure
μ = coefficient of friction.

There is no agreement, however, between experimental results and values calculated from formulae (3) and (4), for guide vanes in closed position.

Prof. R. Thomann, Graz, gives the following expression for the regulating work A_r :

$$A_r = k \, q \, (H + 10) \quad .. \quad .. \quad (5)$$

where $q = \frac{Q}{\sqrt{2 \, g \, H}}$ = reduced quantity of water in sq. meters, H = head in m. For the experimental coefficient K the following values are given : $K = 60 \div 100$ for internal governing gears, $K = 40 \div 80$ for the external governing type. Whether A_r is the regulating work at the open or closed position is not explained. The agreement of formulae (5) with practical experience is by no means perfect though it is better than with formulae (3) and (4). It seems to be impossible to find a mathematical expression for the regulating work which can be applied under any practical conditions, without getting too large a degree of error.

To find the dimension of servo-motors when oil pressure governing is used, the following expression is important.

$$A_r = P_{max} \, S$$

The governors of water turbines should be made sufficiently strong to be safe even under unexpected operating conditions as, e.g., at the preliminary running-in of the turbine.

The questions on the regulating work of impulse water turbines have been solved to a great extent ; the conditions in reaction turbines are much more complicated because of their continually increasing specific speed and accelerated specific flow of water. The regulating work necessary under conditions of runaway speed have still to be ascertained.

THE STRENGTH OF AL-MG-ALLOYS AT THE TEMPERATURE OF LIQUID OXYGEN

By H. MAEDER. (From *Zeitschrift fuer die gesamte Kaelte-Industrie*, Vol. 49, 1942, No. 6, pp. 71-72).

LIQUIFIED gases have been stored and transported in copper or brass vessels up to the present. As copper is now reserved for more urgent war purposes, and the transport costs are high owing to its high specific weight, the possibility of employing light metals as alternative materials will be investigated.

On account of excellent resistance to corrosion and good weldability the Al-Mg-alloys offer especial advantages. Their good shaping and machining properties are also worthy of note.

The alloys "Aluminium Berghaus" Al-Mg5 and Al-Mg7 have been tested at the temperature of liquid oxygen ; the sheets were 4 mm. thick, their state when tested was "soft." At the same time autogenous welded samples of the alloys have been tested too. The yield stress σ_F, the tensile strength σ_B and the elongation to fracture δ_{10} have been ascertained and tabulated in tables 1 to 4 (f=cross sectional area of test specimen). The test bar (100 mm. gauge length) is flat, and of standardized dimensions. For the purpose of the test, it has been put into a light-metal tube closed at the bottom (Fig. 1). A sufficient length of bar protrudes from both ends of the tube to allow for fixing in the testing machine. It is welded to the bottom of the tube from which it protrudes through a slot. When this set-up is fixed in the testing machine, liquid oxygen is poured into the tube and refilled till the oxygen is just boiling. This means that the test bar has acquired the temperature of the liquid oxygen. Now, the loading commences and oxygen is added continuously.

The test results given in the tables have been

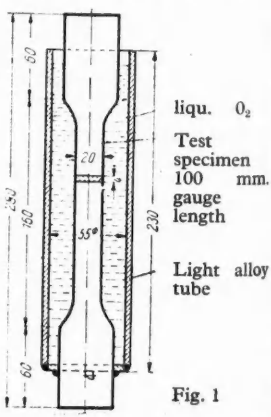


Fig. 1

compared with tests at normal temperature. Both welded and unwelded samples have been tested, and the respective qualities are eloquently born out in comparing them with those at normal temperature.

The present tests confirmed the usefulness of high-strength Al-Mg- alloys as structural material for vessels for liquified gases. With decreasing temperature, the tensile strength, the yield stress as well as the elongation of the alloys increase. Welded parts constitute an exception, here the elongation decreases. However, the values obtained for elongation are in all cases well up to the requirements.

TABLE. I. Al-Mg 5-Sheets at + 20° C. and at—183° C.

Temperature at test + 20° C.					Temperature at test—183° C.				
Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %	Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %
1	79,2	14,2	29,2	24,0	1	79,6	14,4	38,5	27,5
2	79,4	14,0	29,2	25,2	2	80,0	14,7	37,3	27,2
3	79,6	14,2	29,3	25,0	3	80,0	14,7	39,5	32,5
					4	79,8	14,4	36,9	23,6

TABLE II. Al-Mg 5-welded sheets at + 20° C. and —183° C.

Temperature at test + 20° C.					Temperature at test—183° C.				
Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %	Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %
1	80,8	11,5	24,2	9,8	1	79,2	14,5	31,3	11,8
2	80,2	12,5	24,7	11,5	2	79,2	14,1	25,3	8,0
3	80,4	11,2	17,5	14,2	3	79,0	14,9	29,1	9,4
					4	79,0	14,9	26,9	8,5

TABLE III. Al-Mg 7-sheets at + 20° and —183° C.

Temperature at test + 20° C.					Temperature at test—183° C.				
Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %	Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %
1	83,4	17,6	34,6	27,2	1	80,4	19,8	42,3	26,8
2	84,2	16,7	34,4	23,8	2	81,4	20,2	44,2	27,5
3	84,4	17,7	34,9	26,0	3	82,0	19,4	43,4	29,4
					4	82,4	19,3	44,7	30,5

TABLE IV. Al-Mg 7-welded sheets at + 20° C. and —183° C.

Temperature at test + 20° C.					Temperature at test—183° C.				
Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %	Nr.	f mm²	σ_F kg/mm²	σ_B kg/mm²	δ_{10} %
1	85,2	16,2	29,8	15,5	1	81,6	18,8	32,1	4,0
2	85,4	16,1	30,6	17,5	2	81,2	18,8	36,0	5,5
3	84,2	16,2	30,1	14,0	3	81,2	18,8	31,5	8,2
					4	80,2	19,8	34,4	5,5
					5	80,0	19,9	34,0	4,5

MEASUREMENTS

The September, 1942, issue of the "General Electric Review" has been devoted to Measurements. It is introduced with the following words of Lord Kelvin: "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."

Everett S. Lee, Guest Editor of this special issue, wrote in his Editorial: "Measurements are truly essential to certainty of performance, and measuring instruments are a necessary part of all productive equipment and operations."

The special issue contains 10 articles. Two of them deal with apparatus already described in recent numbers of our journal. Three further articles are abstracted on the following pages.*

MINIATURE INSTRUMENTS.

By J. M. WHITTENTON. (From *General Electric Review*, Vol. 45, No. 9, September, 1942, pp. 501-4).

THE article is primarily concerned with the miniature instruments. They have a scale length ranging from 1.5 to 3.5 inches and a normal accuracy within ± 2 per cent of full scale. Some of the more common sizes and shapes of these instruments are shown in Fig. 1. In order to satisfy the very great range of measurements to be made, two basic mechanisms and two auxiliary units as listed in Table I. are used. While the fundamental design of miniature instrument mechanism has not changed during the last few years, the range of measurements has increased due to improved materials and better ways of doing things.

A few words about the kind of mechanism of the class III. instruments may be of interest. In the operation of the thermo-ammeter, current (either a.c., or d.c.) flows through the heater wire (Fig. 2) and heats it in proportion of the square of the current. Two couple wires of dissimilar metals are connected to the centre of the heater wire and thus are heated by the flow of current. This temperature rise of the dissimilar metals at the junction generates an emf, which is a function of the current in the heater and which is indicated by the sensitive d.c. moving element.

The deflection of the pointer varies as the square of the heater current. The low part of the scale is therefore congested, and the pointer indicates only one quarter of the linear distance for 50% current. However, the scale may be expanded at the left, by so changing the pole piece shape of the element as to concentrate the flux where the current strength is weak. Ranges of current in ratio of five to one may be read on these improved instruments.

While rectifier-type instruments can be used effectively only at power and audio frequencies up to approximately 20,000 cycles, thermocouple instruments provide the most practical means of measuring current and voltage at higher frequencies.

Thermocouple instruments will withstand only about 2¼ times normal load and should be used with care.

Design Improvements to Increase Usefulness.

During recent years many improvements have been made in the design of miniature instruments. Chrome steel or tungsten steel alloys, 36 per cent cobalt alloy, and the alnico alloys have been used for magnets, in the order given, to improve current sensitivity of the instruments. The high flux density in the air gap attained with these new materials has made possible d.c. miniature instruments having a full-scale sensitivity of ten microamperes, with sufficient sturdiness for laboratory

*"How to Avoid Overstress in Machine Parts," "E.D.," Vol. 3, No. 4, April, 1942, pp. 126-127. The D-C Telemeter or D-C Selsyn for Aircraft, "E.D.," Vol. 3, No. 9, September, 1942, pp. 315-317.

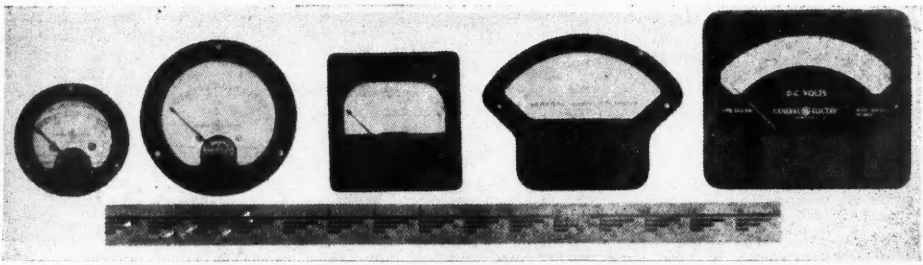


Fig. 1. Variety of modern miniature instruments. Their small size is indicated by the 15-in. rule beneath them.

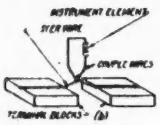


Fig. 2

Schematic diagram of internal heater type thermocouple for use in miniature instruments.

use. The use of these materials has also been extended to damping magnets for a.c. magnetic damping systems.

Continued progress has been made in the reduction of wire sizes as used on direct current moving systems. Copper wire measuring 0.001 of an inch in diameter and insulated with a suitable type of enamel is in common use to-day. This wire that has a diameter about one third that of the human hair, has been of utmost aid in increasing current sensitivity since more turns can be wound on the armature in a given space. Considerable progress has been made in reducing the weight and moment of inertia of the moving systems. Weights in the order of 0.20 grams are not uncommon to-day as compared with much higher weights previously. From all these improvements a better design quality or ability to stand abuse is derived.

Rapid pointer response with controlled overswing is required to meet some requirements of the radio technique. Low moment of inertia and high-torque moving systems are used and result in the response of the pointer to reach normal position being as fast as 0.2 second as compared with one to two seconds normally, and in the pointer overswing being controlled to within 0.5 per cent on 3½ in. scale length instruments.

The range of high-frequency current measurements has been increased to over 150 megacycles with improved accuracy by the use of a new low-impedance concentric conductor design. Full-wave copper-oxide rectifiers have been made with about one-fifth the capacitance of the conventional units to increase their range beyond the audio frequencies without undue frequency errors.

Recent requirements have made it necessary to make instruments that will withstand high shock and vibration. This has been possible by the use of special alloy large radius pivots in combination with stabilized moving systems having control springs. Windings have been treated with special compounds and metals have been properly protected to enable instruments to operate in all kinds of climatic conditions.

TABLE I.

Class	Kind of mechanism	Quantity measured	Range of full-scale measurements	
			Self-contained Instr.	With external equipment
I.	Permanent magnet moving coil (D'Arsonval type)	D.c. current D.c. voltage	20 microamp to 50 A 10 millivolts to 500 V	10 A to limit of shunt 500 V to limit of extern res.
II.	Permanent magnet moving coil with copper oxide rectifier	Rectified A.c. current	40 microamp to 15 milliamp.	
III.	Permanent magnet moving coil with thermocouple	High-frequency current	2 milliamp to 20 A	20 A to limit of thermocouple
IV.	Modified soft-iron vane principle	A.c. current A.c. voltage	5 milliamp to 100 A 1 V to 500 V	5 A to limit of transformer 150 V to limit of transf. or limit of resist.

INKLESS RECORDING.

By P. E. TWISS. (From *General Electric Review*, Vol. 45, No. 9, September, 1942, pp. 511-14).

A NEW type of recording instrument has been developed using the intermittent marking or dotting system. This type has many advantages compared with the pen-and-ink system. The intensive study made with a view of obtaining rates of dotting sufficiently high to obtain a continuous record for all practical purposes, showed that with dotting rates in the order of one per second or faster the record on all normal chart speeds would be satisfactory for commercial circuit analysis.

Any striking mechanism must of necessity deflect the moving system slightly, and the element should, therefore, be given time to recover from the deflection before the next blow. It is necessary that the instrument has a high torque and that a high order of mechanical precision be maintained on all moving parts to reduce to a minimum the amount of deflection given the pointer by this mechanism.

In Fig. 1 is shown a conventional high-torque recorder, originally designed for use with liquid ink, but now equipped with an inkless recording unit in place of the usual capillary pen-and-ink well. This type of instrument has a response of one second and a

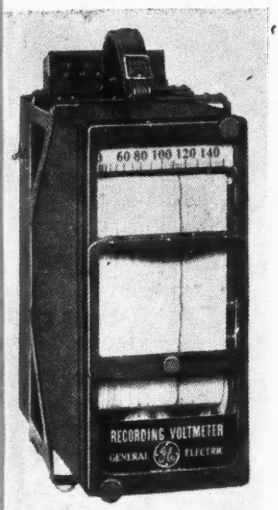


Fig. 1. Inkless recording voltmeter.

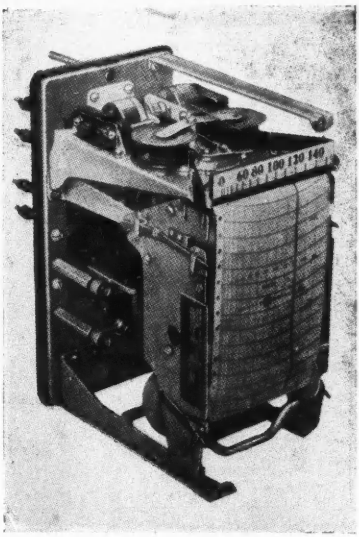


Fig. 2. Inkless recording voltmeter with cover removed.

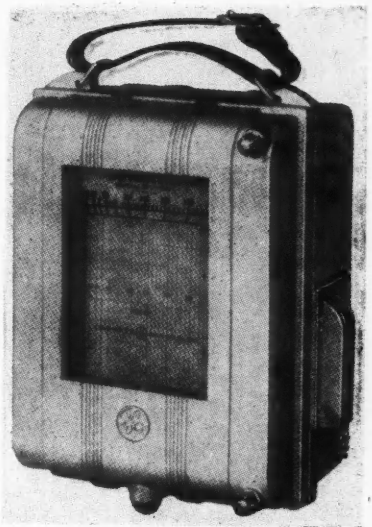
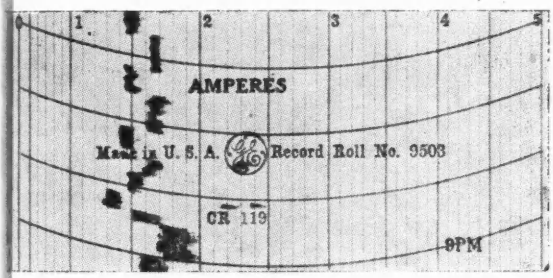
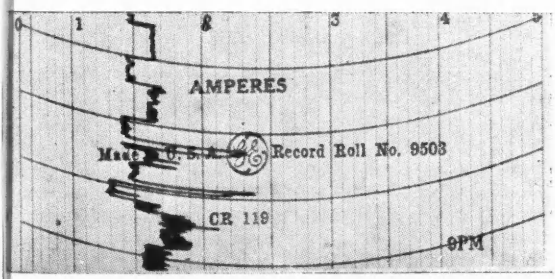


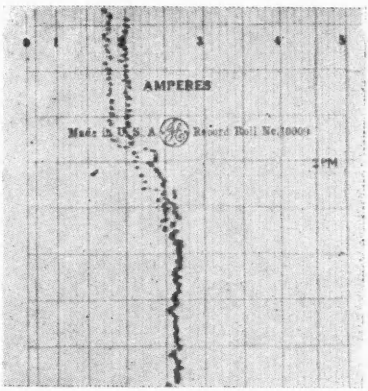
Fig. 4. Portable, weatherproof inkless recording a-c voltmeter

full-scale torque of 230 millimeter-grams. With this high-torque condition it was found that a dotting rate of four per second could be used without causing the element to deviate from its true indicating position. Fig. 2 shows a similar recorder with cover removed, to expose the inkless unit mounted at the top of the instrument.





g. 3. Comparison of records taken with an inkless
p) and a conventional type of ink recorder on an extremely variable-current circuit.



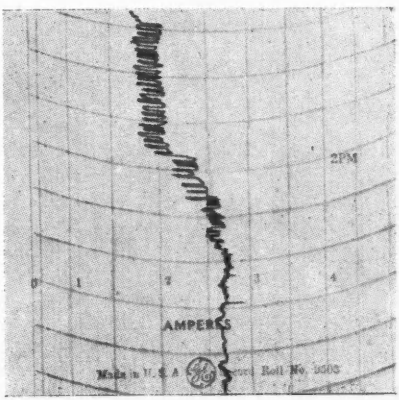


Fig. 5. Current record. Inkless record (top) gives clear indication of maximum and minimum current values on fluctuating load.

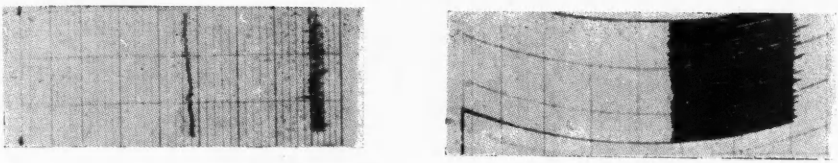


Fig. 6. Current record of extremely fluctuating load. The ink recorder has painted the chart (right) thus giving little useful information, while the inkless record shows clearly that there were two normal operating current values and allows a detailed analysis.

A metal stylus replaces the pen, and the back end of the stylus is deflected downwards by means of a four-point cam, driven by a Telechron motor at 60 r.p.m. This causes the front of the stylus to rise approximately ½ inch above the chart surface and fall by its own weight upon a typewriter ribbon stretched across the top surface of the chart. The rotating cam is located so that the tendency to deflect the pointer is reduced to a minimum.

Advantages.

This device offers a solution to many problems associated with the use of liquid ink, such as freezing, evaporation, spillage and limited length of operation before reservicing. With a chart speed of one inch per hour, a high degree of reliability of operation may be assured for a complete month's time with but a single servicing. For portable instruments such a device offers many conveniences.

The record obtained with the inkless recorder operating as a voltmeter is essentially continuous and as good in every respect as the conventional ink record. The same device applied to an ammeter on a highly fluctuating load will result in a series of dots during rapid pen movements; but study of such a record as shown in Fig. 3 gives even more information than is possible with the ink type, and it is possible to estimate the duration of a short surge.

Upon the occurrence of a surge of one-second duration, which is within the response time of the instrument to record, the chart of the conventional ink type recorder with a chart speed of three inches per hour would travel 0.0016 inches in the two seconds required for the pen to deflect and return to its original position. As the width of the inked line is seldom less than 0.020 in., the chart would show only a single line for the two pen movements. It would be necessary to step up the chart speed at least 60 times to show a spacing between the linked lines so that any idea of time measurement could be obtained. With a dotting rate of four dots per second the intermittent marking recorder would show eight dots for this deflection, indicating that a load change occurred lasting one second. with another second required for the element to return to its original position. These eight dots would permit accurate estimate of this short-time deflection at economical chart speeds.

The torque of the electrical element of the direct marking system using liquid ink must be sufficiently high to overcome the friction of the pen. With the intermittent marking system a full-scale torque of one millimeter gramm is sufficient for the instrument type shown in Fig. 4, weight of which is about 11 pounds. The torque is less than 1/200 of the torque of the larger instrument shown in Figs. 1 and 2. In this portable instrument dotting is accomplished by clamping the pointer between a fixed platen located underneath the scaleplate with a striker bar operated once a second by a Telechron motor. In regard to the lower torque value of the electrical element the frequency of dotting cannot exceed the normal response of the moving system without deflecting the pointer appreciably. However, this rate is sufficient to obtain a continuous appearance of voltage records and the operation of ammeters on fluctuating loads is quite satisfactory, as shown by the charts in Fig. 5 and 6, which were taken with both ink and inkless types of instruments on the same circuit. Fig. 6 shows the great advantage of the intermittent type of recorder.

The power required to operate the ammeter is so low (one volt-ampere), that it is possible to use split-core current transformers interchangeable (200 ampere or more) without the special calibration necessary in the case of ink-type recorders of higher power requirement. Direct current ammeters with a capacity of 125 microamperes may be used for making records, whereas the direct marking type of record instrument is limited to a minimum of one milliampere. New applications are therefore made possible with the inkless recorder which previously required the use of the more expensive photometric recorder.

For studies on distribution systems tests covering long periods are desirable. But a month's operation of a recorder of the usual pen-and-ink system with a lowest speed generally used of one inch per hour produces charts 65 feet long, which are difficult to analyse. With an inkless recorder with a speed of one inch per day the chart of a month's operation has a length of 30 inches.

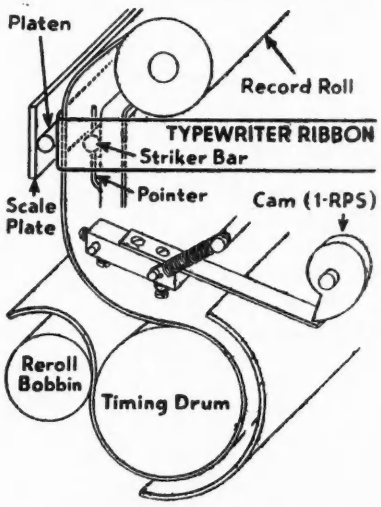


Fig. 7. Diagrammatic view of chart and marking mechanism of the inkless recorder.

LIGHT METER.

By C. L. Dows. (From *General Electric Review*, Vol. 45, No. 9, September, 1942, pp. 505-8).

THE development of reliable light-sensitive cells, generally known as the blocking-layer dry-type, has resulted in a great variety of electrical control applications and light measuring instruments. It was not

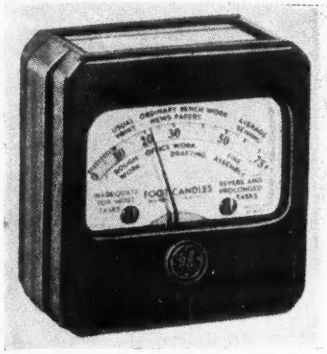


Fig. 1
The light meter. Note that the light cell is at right angles to the face of the scale.

before the introduction of the light-sensitive cell, that convenient and commercially accurate illumination measurements could be made.

Light Meter.

The use of this little instrument (2¼ in. square by 1¾ in. thick) shown in Fig. 1 (over 30,000 now in use) has effectively emphasized the value of good lighting and has greatly contributed to better lighting practice. The standard instrument has a reading of 0 to 75 foot-candles and, when used with a 10 to 1 multiplier, reads up to 750 foot-candles full-scale. All light meters are calibrated at two points, namely 20 foot-candles and 60 foot-candles with direct light of a colour temperature of 2,700 K. The instrument is rated for an accuracy of ±7.5 per cent due to manufacturing tolerances in the cell-microammeter combination, but under certain conditions a greater accuracy may be obtained.

Because of the unique design this light meter has been adapted in a number of modified forms to other light-measuring devices.

The combination of the standard light meter with a properly selected incandescent lamp, placed in a cylindrical hood, which is put onto the window of the meter, may be used for measuring the supply voltage, so that no other volunteer is necessary, when illumination measurements are made.—The exposure meter is used by many thousand photographers.—Special apparatus containing a light-sensitive cell have been designed for measuring the reflecting factor of walls (Fig. 2). These apparatus can also be used to measure transmission factors.—The standard light meter is also

Fig. 2

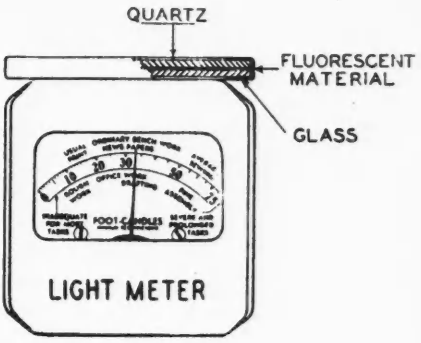


Fig. 3

used for measuring brightness (foot-lamberts or candles per square inch) with the Luckiesh-Holladay brightness meter. The light meter can be slipped out of the brightness meter case and used for conventional work or it can be stored in the brightness meter.

Ultraviolet Meter for Germicidal Lamps.

The radiant energy in the ultra-violet region near 2,537 Angstroms can be measured using a very simple attachment for the light meter. It consists of a metal frame holding together plates of glass and fused quartz with a thin layer of a fluorescent phosphor between them. This combination is placed over the light-sensitive cell as shown in Fig. 3. When the device is attached to a light meter with the quartz plate exposed, the energy causes the phosphor to fluoresce, and this in turn produces a deflection of the light meter. A part of the deflection is due to energy transmitted by the entire attachment, quartz, phosphor and glass. In order to compensate for this, the attachment is turned over, so that the glass is exposed. Since the glass does not transmit any of the 2,537 Angstrom energy, the phosphor no longer phosphoresces appreciably and the meter indicates only the energy transmitted by glass, quartz and phosphor. Thus the difference in the readings under the two conditions is a direct measure of the intensity of the germicidal energy producing the fluorescence.

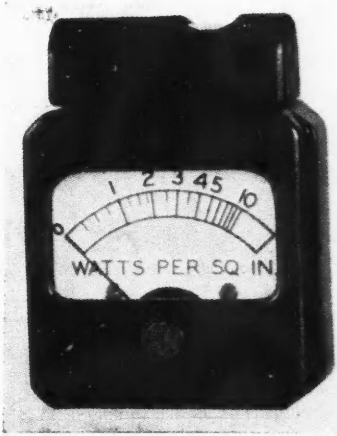


Fig. 4

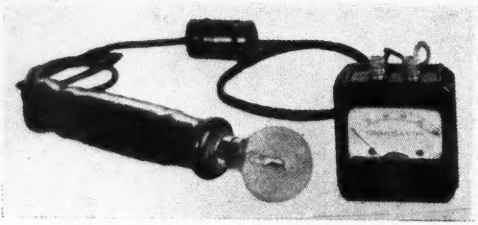


Fig. 5

Meter for Temperature and Radiation Measurements.

The new " drying lamps* " used for many industrial heating jobs require instruments for measuring the concentration of radiant energy and the temperature of the work as it is exposed to that radiation. Various forms of light meters have been found very acceptable for this purpose. The instrument shown in Fig. 4 is a light meter equipped with a new sensitive moving element and a vacuum thermocouple in place of a light-sensitive cell. The radiation thermocouple is equally responsive to radiant energy of wavelengths between 3,000 and 35,000 Angstrom units.

*See THE ENGINEERS' DIGEST, Vol. 2, 1941, pp. 99, 180, and 278.

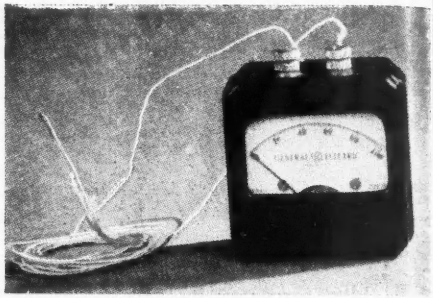


Fig. 6

Another adaptation consists of the light meter with a special low-resistance element and with terminals on the top in place of the light-sensitive cell. An arbitrary linear 0-100 scale allows to measure the concentration of radiant energy or the temperature of an article using a series of curves giving the relation of the readings with the real temperatures. Either the vacuum thermocouple as shown in Fig. 5 or a thermocouple such as shown in Fig. 6 may be used. The range of the meter may be extended by external shunts.

COMPRESSIBILITY

By PROF. DR. J. ACKERET, Institute for Aerodynamics, Swiss Federal Technical College, Zurich. (From *Flugwehr und Technik*, Vol. 2, No. 1, January, 1940, pp. 18-20).

THE lift of a wing depends upon the maintenance of a pressure difference between its suction-side and its pressure-side. If the deviations from normal air-pressure were evenly distributed on both sides of the wing and of equal magnitude but of opposite sign they would amount to say 75kg/m² (15.3 lb/sqft.) on each surface if, as an example a wing loading of 150kg/m² (30.6 lb/sqft.) is assumed. At sea-level this would be $\frac{75}{10{,}000} = 0.75\%$ of the barometric pressure. In the wing theory, the differences in density due to such minute pressure-differences are neglected, and the air is considered to be an incompressible medium.

However, the pressure is not evenly distributed, as has been assumed above. Especially at the stagnation point, where the speed diminishes to zero, the pressure becomes greater ; but this does not change the conception of incompressible flow, as these regions are not extensive.

Let us now consider the conditions at the stagnation point in order to introduce the relevant criterion for compressibility effects, the so-called Mach number $M = \frac{V}{a} = \frac{\text{airspeed}}{\text{speed of sound.}}$

As a first approximation, the pressure-difference at the stagnation point is $\Delta p = \frac{\rho}{2} V^2$. According to the gas laws, to Δp an increase in density, $\Delta\rho$, is co-ordinated. One cannot neglect $\Delta\rho$ as soon as the ratio $\frac{\Delta\rho}{\rho}$ exceeds some percentage. The known equation $p.v = RT$ can be written as $\frac{p}{\rho} = g\,RT$, whereby the absolute temperature T must be known. As the heat conductivity of air is small, the process of compression is adiabatic, and, the additional condition is :

$$p \cdot \nu^k = \text{const.} \qquad k = \frac{C_p}{C_v}$$

(C_p = specific heat at constant pressure,
C_v = specific heat at constant volume).

or $$\frac{p}{\rho^k} = \text{const.}$$

For small changes, logarithmic differentation yields :

$$\log p - k \cdot \log \rho = \log \text{const.}$$

$$\frac{dp}{p} - k \cdot \frac{d\rho}{\rho} = 0$$

For small finite differences : $\frac{\Delta p}{p} = k \frac{\Delta\rho}{\rho}$

Thus, $\frac{\Delta\rho}{\rho} = \frac{1}{k} \frac{\rho V^2}{2} \frac{1}{p}$,

and on substitution for $p = \rho\, gRT$:

$$\frac{\Delta\rho}{\rho} = \frac{1}{2k} \frac{V^2}{gRT}$$

According to the theory of sound, the denominator

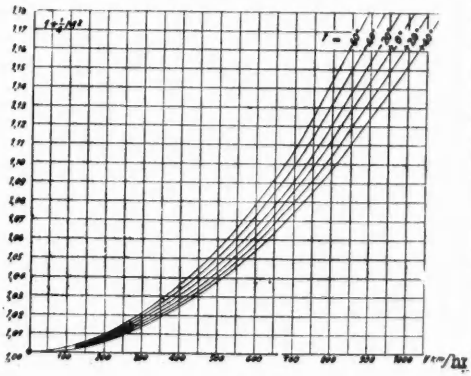


Fig. 1

of the right-hand side is twice the square of the speed of sound a :

$$a^2 = g.k.R.T.$$

So that $\frac{\Delta\rho}{\rho} = \frac{1}{2} M^2$, $\quad M = \sqrt{2 \frac{\Delta\rho}{\rho}}$

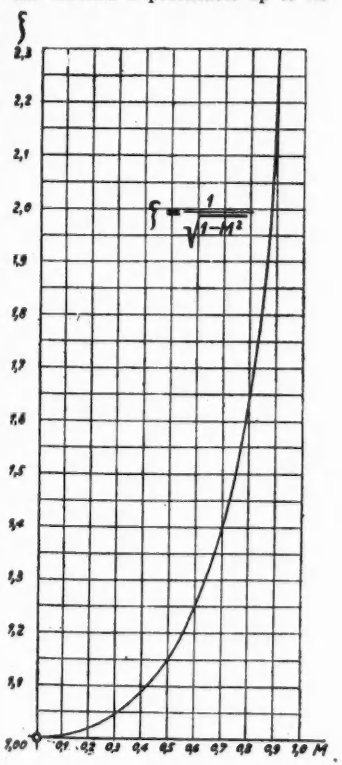
As an example, when $\frac{\Delta\rho}{\rho} \leq 0.10$, the speed V must not exceed 0.446 a. As at sea-level a $\cong$ 340m/sec, the speed would be

$$V = 152 \text{ m/sec} = 547 \text{ km/h} \cong 340 \text{ miles/h.}$$

The change in density effects a change in the stagnation pressure q (the proof of the formulae is omitted here) :

$$q = \frac{\rho}{2} V^2 (1 + \frac{1}{4} M^2 + \frac{1}{40} M^4 + \ldots\ldots)$$

It is sufficient to take $1 + \frac{1}{4} M^2$ as the correction factor by which Bernoulli's formula is to be multiplied. Fig. 1 shows the correction factor for various air temperatures (°C). Prandtl has given a rule to account for the effect of the Mach number on pressure distribution and resultant force. The result is simple, but not valid near the speed of sound (M = 1). The rule is: multiply all ordinates of the aerofoil section perpendicular to the direction of air-flow by $\xi = \frac{1}{\sqrt{1-M^2}}$ (see Fig. 2). The so transformed aerofoil (dotted line in Fig. 3) is an equivalent profile for which the forces are to be found as if the fluid were incompressible. This method is practicable up to M = 0.6. As the



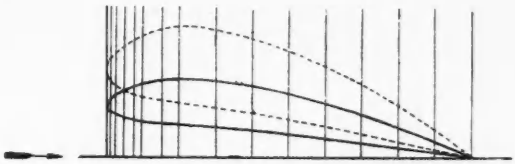


Fig. 3

equivalent profile thickness increases, the drag increases, too. Therefore, to obtain good values, the thickness of the high-speed section should not exceed 12% of the chord.

The effect of compressibility becomes critical for values of M over 0.65. There is good reason for stating that at this stage something like the annullment of the streamline shape occurs. This will be explained by Figs. 4 and 5. Fig. 4 shows the effect of the Mach number on the profile drag C_w as determined by pressure tests. In approaching the speed of sound, the drag increase is very rapid ; for instance, with a symmetrical aerofoil of 12% chord thickness the profile drag increases tenfold by changing from M=0.60 to M=0.75. Similarly, as shown in Fig. 5, with increasing M a considerable reduction of lift is experienced. The aerofoil section is the same as in Fig. 4.

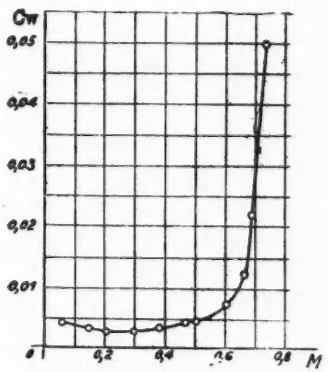
The conclusion from this sudden increase in drag as the speed of sound is approached, is that for all types of aircraft no matter what the further increase in engine power, the same maximum speed of about 1040 km/h (650 miles/hour) could be realised*. (M = 0.85 at sea-level).

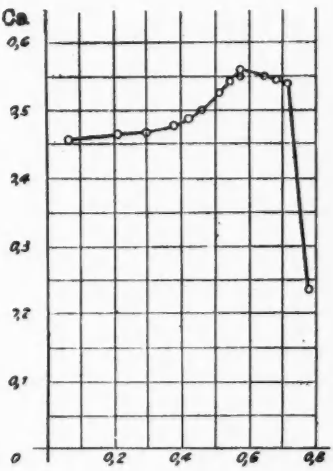
The observation of the aerofoil indicates that at certain points of the section stationary waves appear, and that the wave formation coincides with the beginning of drag increase. The unfavourable effect of the wave-formation seems to lie in the fact that the waves influence the boundary-layer so that there is a tendency to early break-away.

In principle this has been known for a long time, especially Stodola has pointed out, that in nozzles of steam turbines such break-away occurs.

*Compare with the Editorial "High-Speed Flying," *Engineers' Digest*, Vol. 1, No. 3, p. 105.

(Left) Fig. 2.
(Middle) Fig. 4.
(Right) Fig. 5.





THE EFFECTIVENESS OF AILERONS AT HIGH-SPEED FLIGHT

By DIPL. ING. WERNER WIRZ, Institute for Aircraft-Stressing, Swiss Federal College (E.T.H.). From *Flugwehr und Technik*, Vol. 4, Nos. 5 and 6, May and June, 1942, pp. 117-124 and 146-155).

[In abstracting the original paper of fifteen pages, we had to restrict ourselves to a review of the aims and conclusions of the author. The subject is a highly topical one, and if the reader wishes to study the paper in greater detail, we could, on request, make the necessary arrangements.—Editor, ENGINEERS' DIGEST].

To obtain satisfactory lateral control with high-speed aircraft, the question of aileron design demands careful attention. It is known that the stiffness of the wing considerably affects the effectiveness of the ailerons which may be reduced or even reversed[1]. This has been taken into account in British design specifications by safeguarding against reaching the aileron reversal speed. The calculation of this " critical reversal speed " is based on the investigation of Pugsley[2], Cox[3] and Hirst[4], conducted about ten years ago. Whilst the method is simple, it is not satisfactory in all cases ; in addition, one of the assumptions is incompressibility of the air flow which does not hold good for present-day speeds. The treatment of the subject on a new basis furnished by science and research appears to be desirable. Apparently many modern military aeroplanes have been studied as to the effectiveness of their ailerons, but with the exception of short notes[5] nothing has been published.

The present paper attempts to answer the questions connected with the effectiveness of ailerons as they present themselves in modern high-speed aircraft. The significance attached to the torsional stiffness of the wing is especially stressed.

The deflection of the ailerons effects such a redistribution of lift in spanwise direction that a rolling moment M_x ensues. At the same time, a chordwise redistribution of lift takes place, too, whereby the centre of pressure moves towards the deflected aileron. This is shown in Fig. 1, where the increment of the coefficient of lift ΔC_a is represented by the shaded area. The movement of the centre of pressure is about 0.2 t in the example (Maximum thickness of wing 12% t at 30% t, angle of incidence $\alpha = 4°$, angle of aileron $\beta = 10°$, aileron chord is 17% of t), the resultant lift coefficient due to aileron deflection being $Ca + \Delta Ca$. This movement of the centre of pressure produces a considerable torsional moment, which is on port and starboard side of opposite sign. The torsional moment creates an elastic twist of the wing, the magnitude of which is dependent on the torsional stiffness. The twist thus introduced counteracts the change in angle of incidence due to aileron deflection. The rolling moment Mx diminishes, becomes zero, or changes its sign. It appears, that the state of ineffectiveness of ailerons is the most dangerous. Here, no rolling moment can be created, no circular flight path introduced and no lateral control exercised.

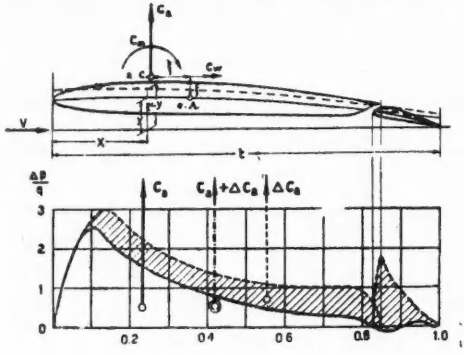


Fig. 1

To get a measure of the effectiveness of the ailerons, we have to refer to a well-defined flight attitude. With a constant aileron angle, the aircraft is brought into a stationary dive. This corresponds to the main loading case 138 of the German specifications[6]. For the C-case-stagnation pressure, here, a stationary angular speed of rolling, ω_x should be maintained. With increasing speed, ω_x decreases, and on reaching the stagnation pressure at which the ailerons become ineffective, the aircraft does not roll in spite of deflected ailerons. With further increase in speed rolling starts in the opposite direction, and with increasing ω_x. The dive test with a constant aileron angle provides the possibility of checking the effectiveness of the ailerons for any given design.

The derivation of the formulae is largely based on the determination of the asymmetrical lift distribution which is rather complicated. However, it is the lift distribution which enables us to deduce figures of merit of great significance for practical work. These are MQ_1 and MR_1, moments about the longitudinal axis of the aircraft at a stagnation pressure $\bar{q} = 1$ kg/m².

M_{Q1} for pure aileron distribution at a deflection $\beta = \pm 1°$.

M_{R1} for rolling distribution with $\frac{b}{2}\frac{\omega_x}{v} = 1$, and linear twist of unity. (b = wing span, v = speed).

A summary of the results and conclusion is given below :

1. In conventional design the movement of the centre of pressure due to aileron deflection (Fig. 1) causes a twist of the wing of opposite sign on port- and starboard side. This effect is dependent on the stiffness of the wing and, results in an asymmetrical change of the angle of incidence, which is influenced also by the speed of the aircraft. There is a critical value for the stagnation pressure $\bar{q}_{cr}$ at which these effects cancel each other, i.e., $\omega_x = 0$.

$$\bar{q}_{cr} = \frac{M_{Q1}}{M_{R1}} \cdot \frac{1}{\varphi_1}$$, the appropriate stagnation pressure of flight is :

$$q_{cr} = \frac{M_{Q1}}{M_{R1}} \cdot \frac{1}{\varphi_1} \cdot \frac{1}{k_c}$$

φ_1 Effect of zero moment distribution (for equilibrium about the longitudinal axis) $k_c = 1 + \frac{1}{2} M^2$, M. . . . Mach number.

(1) E. Amstutz, On the Stiffness of Aircraft Members, ISTUS report No. 7, 1939.

(2) A. G. Pugsley, Aerodynamic Characteristics of a Semi-Rigid Wing, A.R.C., R. & M. 1490, 1932.

(3) Robee Cox and A. G. Pugsley, Theory of Loss of Lateral Control due to Wing Twisting, R. & M. 1506, 1932.

(4) D. M. Hirst, Calculation of Critical Reversal Speeds of Wings, R. & M. 1568, 1933.

(5) Messerschmitt Me 109., Flugsport No. 23, 1940.

(6) German Design Specifications for Aircraft, Edition December, 1936, No. 1, Art. 1152.

Below q_{cr}, the effectiveness of the ailerons is reduced, above q_{cr} we obtain the reversal effect of ailerons.

2. In the proximity of q_{cr} there is a dangerous region in which the desired effect cannot be obtained. The limits of this region are dependent on the magnitude of the control force.

3. The location of the elastic axis is of importance if equilibrium of moments about the longitudinal axis is to be maintained without rolling. The effectiveness of the ailerons can be increased by pushing the elastic axis towards the trailing edge.

4. The elastic twist coupled with aileron effect offers some advantages for high-speed flight. Here, the lift increment increases more rapidly than the moment increment, so that a smaller aileron deflection will be sufficient.

5. At very high speeds the arrangement of the ailerons must be such as to avoid shock waves. It appears to be of advantage at high-speeds to lock the ailerons and deflect some type of drag increasing device at 90° to the wing. Simultaneously, two additional advantages would be achieved : The diminution of the danger of flutter, and reduction of the induced yawing moment.

6. From the design point of view, two possibilities are open for securing sufficient effectiveness of the ailerons.

(a) The conventional arrangement of ailerons at the trailing edge requires great stiffness of the wing. For cases where the location of the elastic axis is of importance, a gull-like plan form of the wing may be advantageous.

(b) Such an arrangement of the ailerons to be provided as to gain a supporting effect by elastic twisting. The stiffness of the wing should not be greater than necessary for safety against vibration.

7. The stressing of wings under torsion is based on flight cases with deflected ailerons. The torsional moment at the section where the aileron begins is taken as reference. It is proportional to the aileron angle and the stagnation pressure.

The case 138 according to German design specifications has been analysed. It appears that these are framed on the rigid wing, as the condition $\frac{\omega_x}{v} = \frac{0.10}{b}$ required by the specification cannot be fulfilled by the majority of present-day aircraft.

The necessity arises to find the conditions which correspond to reality more closely. It should be possible to apply such an aileron angle at maximum stagnation pressure in a dive, as to keep the aircraft at full throttle in the lateral position. Finally, the manœuvrability at maximum level speed must be defined. A criterion for this is the time necessary to obtain stationary movement in a circular path of given radius, measured from the time of application of the ailerons. To satisfy these conditions certain values must be obtained for the various figures of merit evolved in the present paper.

MACHINE FOR COMPRESSING THE SURFACE OF SCREWS TO IMPROVE FATIGUE STRENGTH

(From *Die Werkzeugmaschine*, Vol. 6, No. 11, June, 1942, p. 331).

ACCORDING to patents of Prof. Föppl, of Germany, a surface compressing machine has been developed which compresses the surface of screw threads.

It is pointed out that screw threads can be stressed statically or dynamically. When stressed statically the thread is not or seldom subjected to a constant variable loading. The dimensions of the screw or bolt are, therefore, governed by the strength of the material, which in turn is chosen to suit the load requirements. Thus for highly stressed bolts high quality materials are employed having high strength properties. The condition of load applied to the screw is appreciably altered when it is subjected to dynamic loads. Such screws or bolts are subjected to a definite static stress in tension upon which is superimposed a fluctuating load. If screws subjected to dynamic loads were designed according to the ordinary rules of strength, they would fail by fatigue. Such fatigue failures, which are not unknown in machine tool design, are caused by notch effect, and are present at the root of the thread in every screw. Under conditions of static load plastic deformation occurs and governs the strength of the screw and is not harmful, providing the screw has been correctly calculated. When screws are subjected to alternating load, i.e., dynamic load, continuous transient stress raisers occur at the root of the thread which will ultimately end in a fatigue failure even though the magnitude of the alternating load is of a relatively low order. Any pre-stressing which will have been applied to the screw will have little effect on the fatigue strength. In addition to the notch effect caused by the thread root, other notch effects, such as the machine finish and those caused by the production method have to be taken into consideration.

It has been found that when the screw or bolt is subjected to a surface compressing operation, the notch effect can be appreciably reduced and the fatigue strength can be increased from 100 to 180%. The higher strength properties of the material from which the screw is manufactured, the greater will be the

increase in fatigue strength, due to surface compressing treatment.

Owing to the lack of suitable machines for compressing the surface of such machine parts as bolts, etc., no practical applications have been made to gain the advantages which have been claimed by surface compressing. It is, therefore, interesting to note that the machine designed by H. Lindner, of Germany, and shown in the figure has been purposely designed for applying a surface compressing treatment to screw threads. It is claimed that the improvement in fatigue strength claimed by surface compressing has been fully realized after treatment in the machine which, it is also claimed, operates economically. The machine has a further advantage that all types of screw threads can be treated. The machine, which operates electro-hydraulically, will be described in detail in a further article in the near future.

MICROSCOPIC METHOD OF MEASURING SURFACE ROUGHNESS

(From *Die Werkzeugmaschine*, Vol. 6, No. 9, May, 1942, pp. 267-268.)

A SPECIAL microscope has been developed which allows a comparison between two objects to be made directly. The images of both objects lie side by side without a line of separation, spoiling the comparison between the two images. The microscope can be used so that the whole ocular field of vision is utilized for a single object instead of half the ocular field of vision for two objects. The instrument which is shown in Fig. 1 serves as a powerful, sturdy workshop microscope.

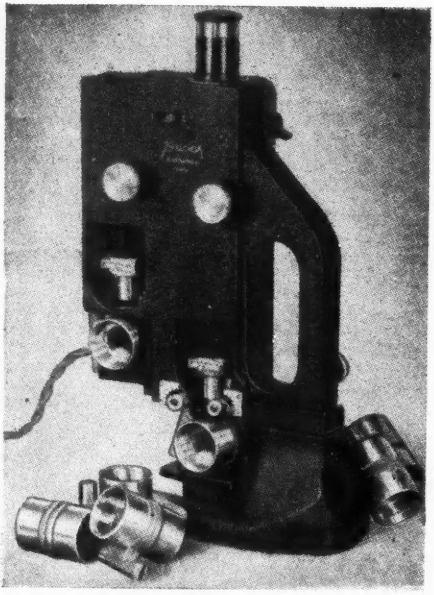


Fig. 1

A surface comparator with low and medium magnifications and one not requiring the services of a trained microscopist, but one which can be safely used by ordinary workshop personal, has long been a workshop requirement. The instrument shown diagrammatically in Fig. 2 is said to meet these requisites.

When used as an optical comparator for comparing two objects, each having half the field of vision, the incandescent bulb for illumination is mounted in the housing " b." The lenses " m " and " n " are mounted in the dovetail slides " r," and the eyepiece " a " is screwed into position. The blank or master specimen " k " is placed in the V block " e " and is raised until it meets a stop and then locked in position by a set screw. When inspection is being made of specimens with flat surfaces, the V block is withdrawn from the slide and inverted so that the flat surface can be raised or lowered by the screw mechanism " g." When the circumference of round specimens is being examined a locking device is provided as shown by the retaining rollers " k " which clamp the specimen into position. The images are focussed by rotating the knobs "c" and " d."

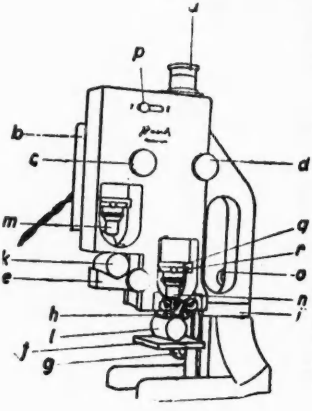


Fig. 2

When the object to be examined is to be viewed over the whole ocular field, the knob " p " is moved across the slot to the position marked " l." The specimen is then mounted on the table " f " in the same way as has been pointed out

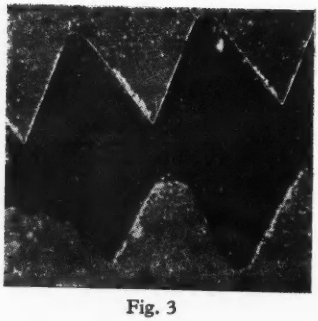


Fig. 3

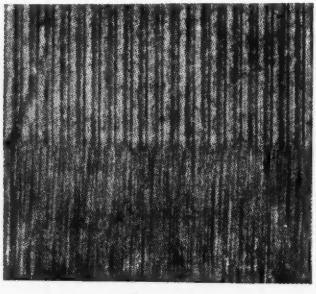


Fig. 4

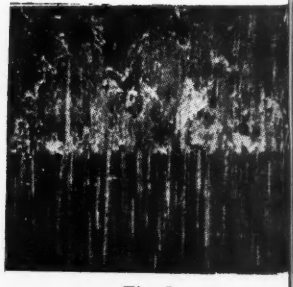


Fig. 5

above and is focussed by means of the knob "d."

The kind of results obtained with the microscopic comparator is shown in Figs. 3 to 5. Fig. 3 shows a comparison between a new and used screw thread, Fig. 4 a comparison between the finish obtained on brass and steel by turning, and Fig. 5 shows a seized steel shaft and a satisfactorily ground steel shaft.

When the specimen to be examined is larger than can be accommodated on the table "f," the microscope can be removed from the stand actuating the screw "o," and set directly above the specimen. The retaining rollers "h" then act as the support.

STRENGTH of PLASTIC MOULDINGS from COMPOSITE MATERIALS

By Dr.-Ing. H. R. Jacobi, Troisdorf, Koeln. From *Kunststoffe*, Vol. 32, No. 1, January, 1942, pp.1–9.)

With mouldings of intricate shape and moulded from laminated paper or fabric, it often happens that for some reason the fabric or paper laminations rupture and a reduction of mechanical strength will occur, e.g., where rapid change in section arises. With such mouldings, the wall thickness can be increased and the critical part may be moulded by additional standard powdered or macerated moulding material which, together with the lamination, gives a composite moulding material.

Such a dislocation of the laminations is shown by Fig. 1, which illustrates part of a cylinder, moulded from laminated fabric. Sometimes when the rupture occurs, the moulding at this part consists of resin only: this part is the starting point for future rupture under operating conditions. Fig. 2, which shows a 40 times enlargement is of the ruptured edge of a cup moulded from laminated paper, the surface between the ruptured fibres being filled with pure resin.

The moulding and control of the moulding process ought to be so designed that the laminations would not be dislocated, but this is not always possible. The use, therefore, of composite materials is necessary to reduce dislocation to a minimum and thus avoid the rupture of the fibres. The strength of these composite materials has been experimentally studied, the following moulding materials having been used :—

Z1	..	Standard phenolic moulding powder, filler cellulose (paper flocks).
Z2	..	Standard phenolic moulding powder, filler paper flakes
Z3	..	Impregnated paper laminations (paper sheets).
S	..	Standard phenolic powder, filler: wood flour.
T1	..	Standard phenolic powder: filler: fabric flock.
T2	..	High-impact strength material, filler: fabric shreds.
T3	..	Impregnated fabric laminations.

Plates have been moulded in the following compositions :—

Z3+Z1+Z3	Z3+T2+Z3
Z1+Z3+Z1	T2+Z3+T2
Z3+Z2+Z3	Z3+S
Z2+Z3+Z3	

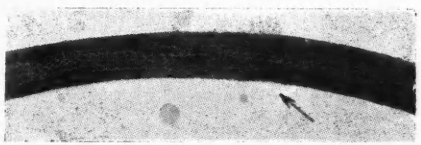


Fig. 1. Section through a cylinder moulded from laminated fabric (Type T3). The laminations are dislocated in the direction of the arrow.

Fig. 2. Burst cellulose fibres on the edge of a moulded cup. Material: laminated paper (Type Z3) 40 × enlarged, reproduction 5/6.

The moulding pressure was 300 kg/cm², the total wall thickness Z3+S=5.25 mms, all the other plates 10 mms. The plates were cut in bars, 15mms wide and 120 mms long.

Three types of moulding procedures were employed during the experiments :—

(*a*) The unlaminated moulding material has been precured, the thickness was 1 mm.

(*b*) As before, the thickness 2 mms.

(*c*) Not presented at all.

Precuring was carried out up to a state when proper fusing was possible in the finish-moulding operation. Using "a" and "b," the laminations remain parallel and undisturbed—with "c" there was some difference in the wall thickness.

Half of the plates were moulded with the laminations outside and the standard moulding powder inside, while the other half were moulded the other way round, i.e., laminations inside and the powdered material outside.

Fig. 3 shows a test bar, broken during the impact testing. Material: Z3+T2+Z3. T2 precured according to "b."

Fig. 4 shows a composite plate made from material T2+Z3+T2. The powder T2 was not precured and the laminations Z3, are a little deformed.

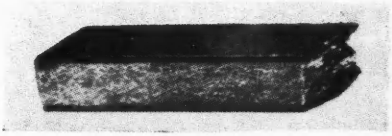


Fig. 3. Composite material: outside laminated paper (Type Z3), inside fabric filled moulding material (Type T2) precured. The laminations are not disturbed.

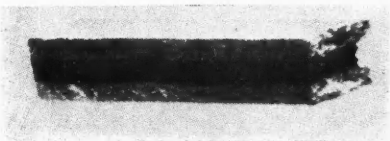


Fig. 4. Composite material: outside fabric filled moulding material, not precured, inside laminated paper (Type Z3). The laminations are disturbed.

The strength was checked parallel and perpendicular to the laminations, and the best average results were found from the composition Z3+T2+Z3. Regarding the question of internal or external lamination, there is no difference with stresses parallel to the laminations, but with perpendicular stresses large variations in the strength have been ascertained.

With stresses parallel to the lamination it may be assumed that the total strength of the composite moulding is the sum of the strength of all the component materials. However, practice shows that by adding

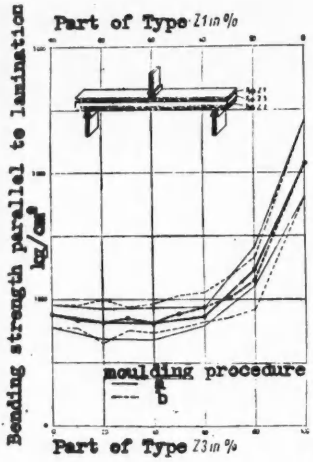


Fig. 5

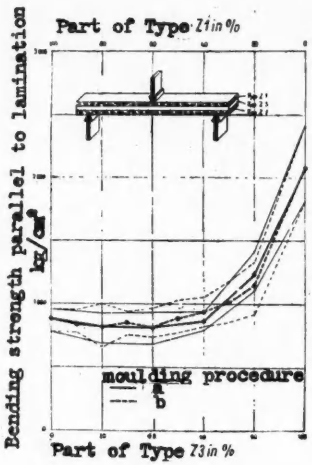


Fig. 6

small quantities of moulding powder, the strength of the laminated component decreases. It appears that when a rupture occurs the immediately neighbouring laminations become overstressed and fracture too.

The highest strength is achieved with outside plating of Z3 stressed perpendicular to the laminations.

The results of the experiments are shown, for material Z1+Z3+Z1, in graphs 5 and 6, the stress being parallel and perpendicular to the laminations. The laminations are internal. In the graphs 7 and 8, the result of the same experiment is shown, however, with external lamination.

In graph 9 the composition Z3+S is shown, where " S " is alternatively under tension or compression, that is, on top or bottom of the laminated part, and the stress appears along or across the fibres. Over 4,000 measurements (on 100 plates each cut in 40 test-bars) have been carried out and the results may be summarised as follows :—

(1) With stresses parallel to the laminations and with regard to additional unlaminated moulding material, the strength declines rapidly if unlaminated moulding material is added.
(2) With composite materials the strength declines rapidly with stresses perpendicular to the laminations.
(3) There is very little loss in strength when the laminated material is outside or on the tension side and the stress is perpendicular to the lamination. In this case the application of composite material is extremely advantageous.
(4) The results may be improved by using basically the same material (e.g., Z2+Z3, or T2+T3).
(5) Materials filled with flakes produce better products but larger dispersal of strength occurs than with materials filled with flock.
(6) Precuring of the unlaminated material has very little effect on the strength of the finished product. It is advantageous only when using flake filled material and when the mouldings are submitted to shock.

Plates consisting of three sheets : lamination + powder + lamination or powder + lamination + powder are flat when leaving the mould and remain so. Plates consisting of two sheets only (lamination + powder) are always bent owing to the different contraction coefficient of the materials.

Mathematical Formulæ.

In dealing with the strength of the composite moulding materials, an exact mathematical analysis is not possible owing to the lack of information regarding the deformative properties of the materials concerned. The analysis may be simplified, however, by assuming that up to the point of rupture, HOOK'S law can be applied. Furthermore, it can be assumed that the modulus of elasticity is equal for all individual materials concerned. Under these conditions the following formulæ may be used for strength determination.

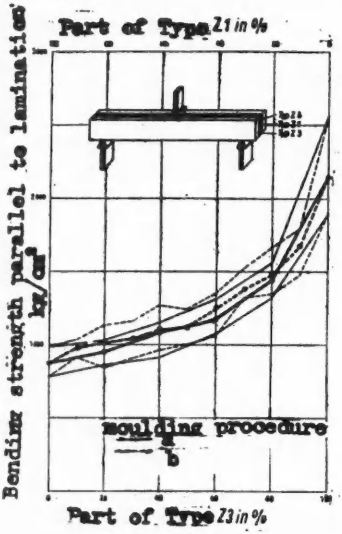


Fig. 7

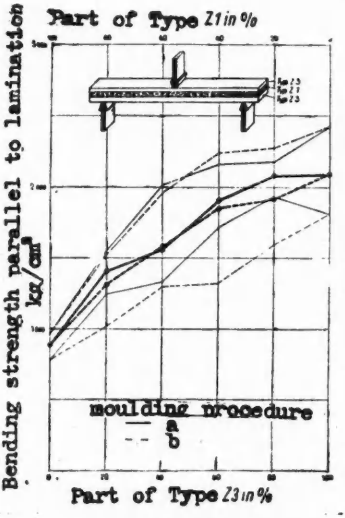


Fig. 8

Impact Strength Parallel and Perpendicular to the Laminations.

The total energy absorbed by the test bar is the sum of the energy quantities absorbed by the different materials :

$$A'F = A'_1aF + A'_2bF.$$

Where A' = Impact strength of the composite material, A'_1 and A'_2 = impact strength of the individual components, F = cross section of the test bar, " a " and " b " = constants, whereby a+b = 1.

Therefore :

$$A' = aA'_1 + bA'_2 \quad .. \quad (1)$$

The graphical representation of Equation 1, is a line. (Shown by thin line on graphs 10, 11.)

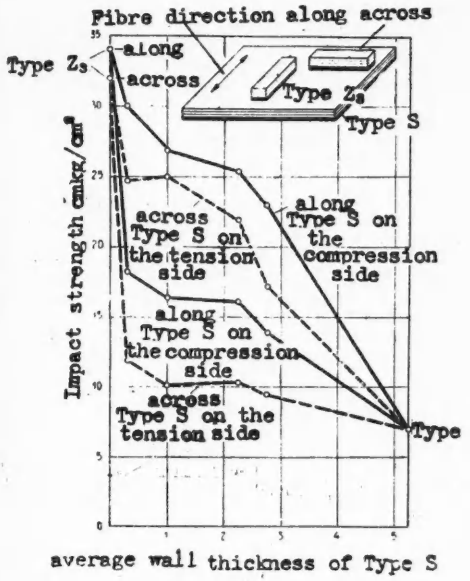


Fig. 9

Bending Parallel to the Laminations.

The total bending moment acting upon the test bar $M=\sigma W$ is the sum of the moments:

$M_1=\sigma_1$ a.W, $M_2=\sigma_2$ b.W., where σ, σ_1, σ_2, are unit stresses, W is the section modulus, and $a+b=1$, therefore $\sigma=\sigma_1 a+\sigma_2 b$ .. .. (2)

The graphical representation of Equation 2 is a line. (Shown in thin line on graph 12).

Bending Perpendicular to the Laminations.

The moment $M=\sigma$. W is the sum of the two moment M_1 and M_2

$$M_1=\sigma_1 W_1 \qquad M_2=\sigma_2 W_2$$

where total test bar W, according to the rectangular section of the $\frac{B H^2}{6}$, according to the factors "a" and "b" . . . . (a+b=1).

$$W_1=\frac{B (bH)^2}{6}=b^2 W$$

$$W_2=\frac{B [H^3-(bH)^3]}{6H}=(1-b^3) W \qquad b=1-a$$

$$\sigma=\sigma_1 b^2+\sigma_2 (1-b^3)=$$
$$=\sigma_2-(\sigma_2 b-\sigma_1) b^2=$$
$$=\sigma_2-(\sigma_2 b-\sigma_1) (1-a^2) \qquad .. \qquad .. \quad (3)$$

The graphical representation of equation 3 is a parabola. (Shown on graph 13 as a thin line.)

The results of the experiments are not in conformity with the theroretical lines. Hook's law can not be

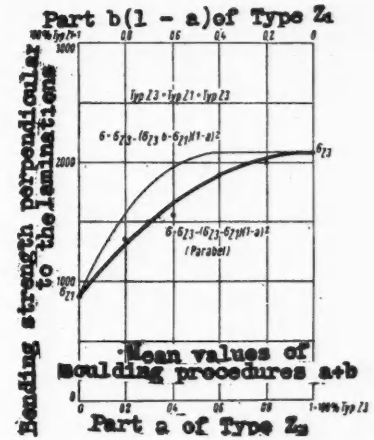

Part b(1 - a)of Type Z1
Bending strength perpendicular to the laminations
Typ Z3 · Typ Z1 · Typ Z3
(Parabel)
Mean values of moulding procedures a+b
Part a of Type Z3

Fig. 13

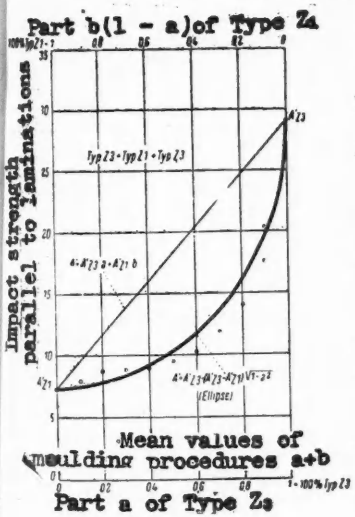

Part b(1 - a)of Type Z1
Impact strength parallel to laminations
Typ Z3 · Typ Z1 · Typ Z3
(Ellipse)
Mean values of moulding procedures a+b
Part a of Type Z3

Fig. 10

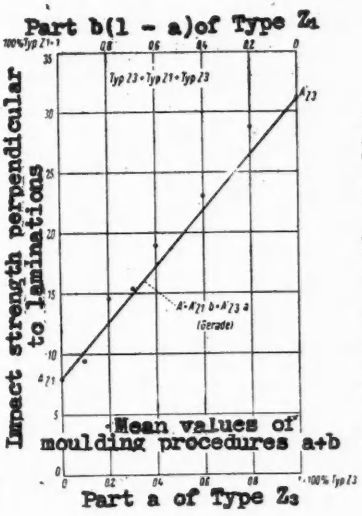

Part b(1 - a)of Type Z1
Impact strength perpendicular to laminations
Typ Z3 · Typ Z1 · Typ Z3
(Gerade)
Mean values of moulding procedures a+b
Part a of Type Z3

Fig. 11

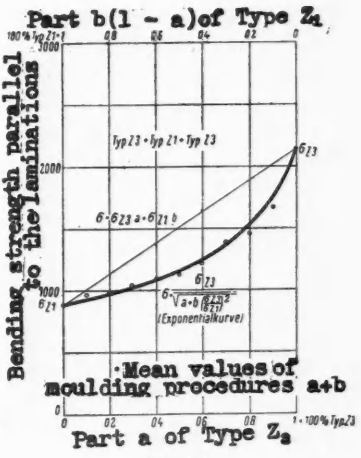

Part b(1 - a)of Type Z1
Bending strength parallel to the laminations
Typ Z3 · Typ Z1 · Typ Z3
(Exponentialkurve)
Mean values of moulding procedures a+b
Part a of Type Z3

Fig. 12

applied up to the point of rupture. It is possible to establish equations with approximate value for all the materials concerned, e.g., for the composite Z3+Z1+Z3 :

(1) Impact parallel to the laminations.

$$A' = A'Z_3 - (A'Z_3 - A'Z_1)\sqrt{1-a^2}$$

(Ellipse shown on graph 10 as a thick line).

(2) Impact perpendicular to the laminations :

$A' = A'Z_1 b - A'Z_3 a$ (Line shown on graph 34).

(3) Bending parallel to laminations :

$$\sigma + \frac{\sigma Z_3}{\sqrt{a + b\left(\frac{\sigma Z_3}{\sigma Z_1}\right)^2}}$$

(Exponential curve shown on graph 12 as a thick line).

(4) Bending perpendicular to the laminations :

$$\sigma = \sigma_2 - (\sigma Z_3 - \sigma Z_1) \quad (1-a^2).$$

(Parabola shown on graph 36 thick line).

Summary.

The strength of mouldings of composite material is influenced by the strength of the individual materials, by their relative position, and by the stresses acting on the laminated components. It is possible to calculate the strength of the composite material by considering the composition.

THE MOST EFFICIENT LAY-OUT OF ELECTRIC ARC FURNACE STEEL WORKS

By HEINRICH MUELLER. (From *Stahl und Eisen*, Vol. 61, No. 29, July, 1941, pp. 685-694).

(*continued from Vol.* 3, *p.* 429).

A considerable volume of fumes charged with dust escape from arc-furnaces, for the evacuation of which little provision has been made in furnace or in building design. The fumes pass through rooms where cranes travel, and their high density prevents them from escaping by natural draft under these conditions. Expensive auxiliary plant (fans, blowers) has been added in order to overcome this inconvenience. The specimen analyses at the end of this article on p. 27 shows how serious this question is.

Another difficulty arises from the handling of electrode and furnace roof, if the crane runways of existing steelworks are not sufficiently elevated above floor level.

Figs. 1, 2 and 3 show examples of arrangements of arc furnaces in open-hearth steelworks. The furnace, Fig. 2, has a short spout, which was made possible by the use of very low electrode supports, but charging is still by means of an improvised gear. The door is not near enough to the crane, and precious space in the foundry hall is lost. The arrangement, Fig. 3, is inconvenient when several furnaces are placed side by side, as crane movements for charging and for discharging are partially in opposite directions. These three furnaces are for charging by hand or by chutes.

Modern top-charge furnaces are sited in the same way. Fig. 4 shows a medium-size, top-charge furnace placed in the foundry bay, the furnace bay being rather narrow. The furnace chamber moves into the furnace bay for charging. This example shows how the lay-out of the furnace is determined by the existing building. Fig. 5 shows a new type 30-ton furnace, placed in a Siemens-Martin open-hearth steelworks. This plant contains big open-hearth furnaces and the crane runway

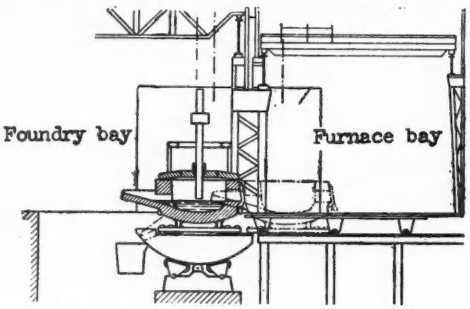


Fig. 4

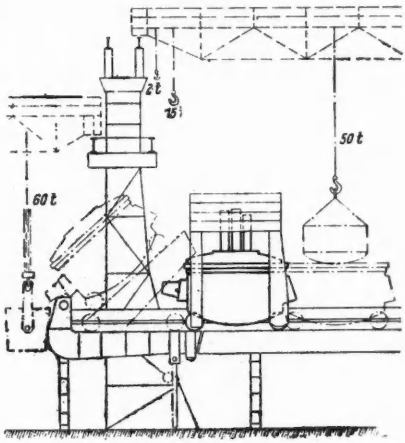


Fig. 5

supports between the bays are very large. Since for certain reasons the furnace had to be placed on an elevated platform, there would not have been enough space between the raised electrodes and the runways to allow for tilting. These difficulties have been overcome by constructing a top-charge furnace with fixed electrode supports and a moving chamber. The chamber is placed on a bogie, and for charging, it runs into the furnace bay, and for pouring the steel it runs on a cradle into the foundry bay, the electrodes remaining stationary. The latter are drawn out of the roof altogether. The cradle is tilted by 42° by means of racks. To remove the slag, the furnace is tilted backwards by 8-10°, in which movement the electrodes participate

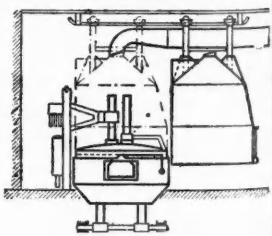


Fig. 6

Hood covering a furnace to collect fumes ; shown in withdrawn position before pouring out the steel.

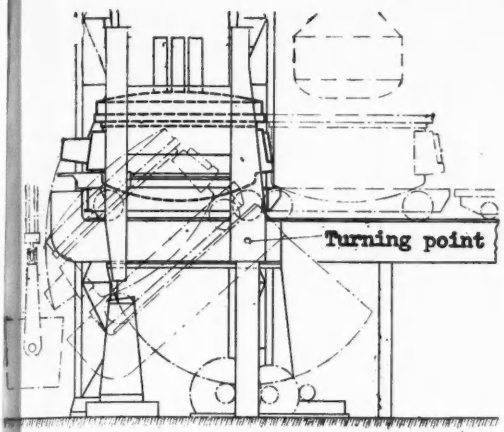


Fig. 7. Project of a furnace with stationary electrode supports ; chamber moving only for charging.

too. Heat losses through the electrode apertures in the roof are small, and the slag does not solidify in the few minutes before pouring out the steel. The whole operation : pouring, reconditioning of furnace and recharging takes only some 15 minutes. Power consumption varies from 600 to 800 kWh per ton of molten steel, the electrode consumption from 6,5 to 7,5 kg per ton. The advantages of this furnace are :

(1) Short connection between transformer and electrode holders.
(2) Short cooling water connection.
(3) Short spout.

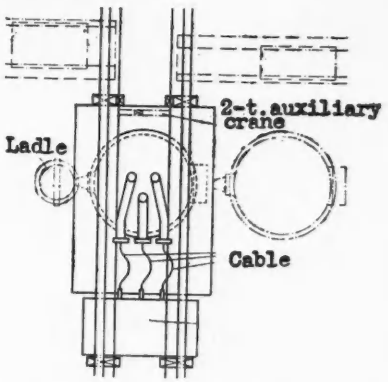


Fig. 9. Cross-section through the upper part of the fume bay.

(4) Little movement of the end of the spout during tilting.
(5) Large tilting angle.
(6) Reduction of breakages of electrode fittings.

Consideration must be also given whether the furnaces should be placed on the ground floor or on an elevated platform. This latter arrangement is generally more advantageous.

Another problem is the evacuation of escaping fumes. Different arrangements have been tried out, ranging from simple skylights or roof ventilators, to roof ventilators combined with blowers on the ground floor and hoods over the furnace. An installation of this kind, provided with a powerful fan (Fig. 2) is

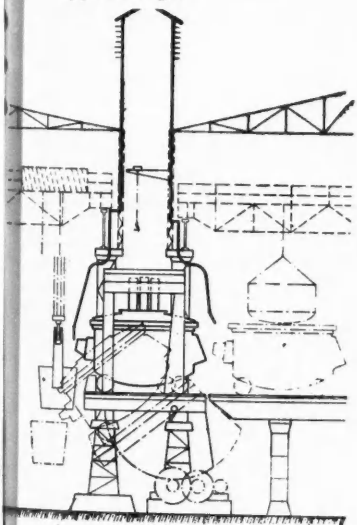
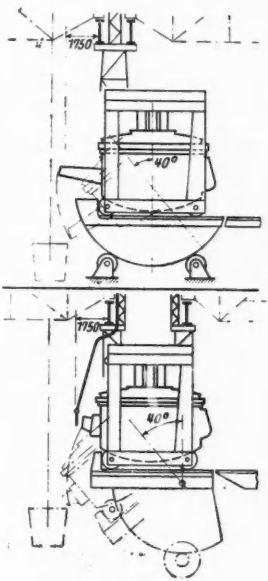


Fig. 8. Furnace (Fig. 7) placed in a separate fume bay.



Figs. 10 and 11

Figs. 10 & 11. Bridging the space taken up by the crane runways in the old type steelworks and in the suggested new arrangement.

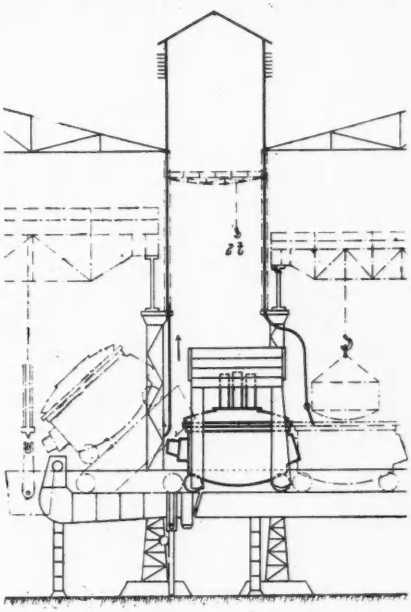


Fig. 12. Fig. 5 type furnace placed in the fume bay according to the suggestions of the author.

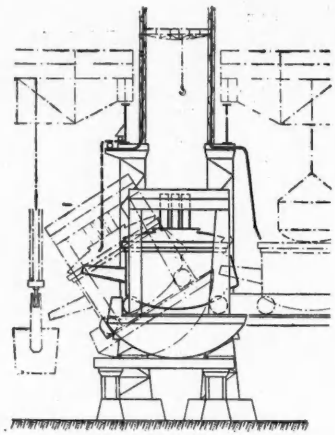


Fig. 13. A rolling type furnace placed in the new steelworks.

shown in Fig. 6. It has an efficiency of 70% ; but such an installation is difficult to arrange on a top-charge furnace.

To overcome all these difficulties, the author proposes to adapt the lay-out of steelworks to the furnace design. Fig. 7 shows a simplified version of furnace (Fig. 5) which is particularly suited for new type steelworks. The movement of the furnace towards the foundry is eliminated, and the furnace tilts from its normal position without the electrodes. The centre of this rotative movement is beneath the furnace door, in order to bring the tip of the spout still more within reach of the foundry crane. The rest of the arrangement, including tilting by 8-10° in both directions is the same as for Fig. 5. Separation of centre gravity and centre of rotation needs a strong construction of the parts concerned, unless there are counterweights.

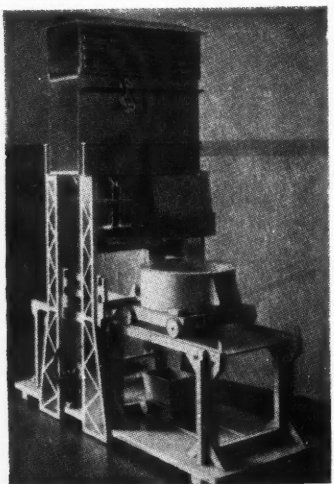


Fig. 14. Model of a furnace. The furnace roof is suspended on the runways (lower part of the screening taken away).

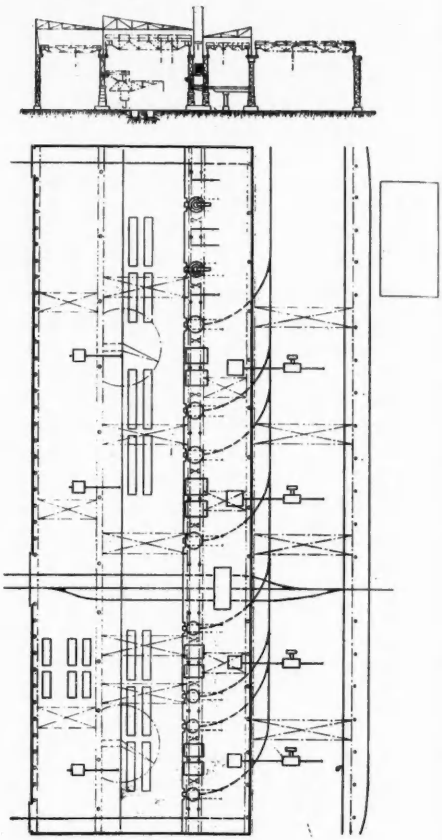


Fig. 15. Plan of a new type electric steelworks.

This design now permits the furnace to be enclosed in order to collect the escaping fumes. Either the supports of the twin crane runways are rearranged as two separate structures (Figs. 8 and 9), or the crane rails are separated so widely on large supports as to allow for electrode changing in the space between them. The width of this new furnace bay or fume bay, is about 0.8 of the furnace diameter : there are no travelling cranes on continuous runways, but small individual auxiliary jib or travelling cranes. The furnace illustrated in Fig. 5 may be arranged in a similar way ; of the usual types, the most convenient for installing in a modern steel works are those moving on a horizontal platform.

Figs. 10 and 11 compare the old and the new arrangements, and the difference in the path of the spout tips when tilting, should be noted. Sheet-metal screens enclose the furnace and mount to the roof, thus forming a funnel for the evacuation of the gases and vapours. The lowest parts of the screens are removable, but allow for the small tilting movement of the furnace as previously mentioned.

This lay-out limits to a certain extent the size of the furnaces in a plant. If the furnaces are not too different, the cross-section of the plant must be based on the dimensions of the largest furnace ; if the sizes differ widely, furnaces should be arranged in groups.

If the furnace shown in Fig. 7 is not considered acceptable, the furnace shown in Fig. 5 may replace it in modern steelworks.

There is yet another possibility: to disperse with gantry crane-like superstructure and to suspend the furnace roof on the runway girders or on supports fixed to the runway columns (Fig. 14).

Fig. 15 is the project of an electric steel plant with 4 medium size and 4 large size arc furnaces, and 2 low-frequency induction furnaces.

As for economy, the arrangement of 2 crane runways or enlarged runway supports seems to increase costs. But on the credit side we have a reduction in the span of the travelling cranes in the furnace bay. It is also possible (especially with stationary electrode supports) to place the runways in the furnace bay at a lower height. Special expensive ventilation plant becomes unnecessary.

Quantity of dust	8,5 g/Nm³		4,5 g/Nm³		4,5 g/Nm³	
	%	%	%	%	%	%
Fe^2O^3	20	= 14 Fe	19	= 13,3 Fe	19	= 13,3 Fe
Cr^2O^3	1,5	= 1 Cr	1	= 0,7 Cr	2	= 1,4 Cr
NiO	0	= 0 Ni	0	= 0 Ni	0	= 0 Ni
MnO	1,5	= 1,2 Mn	4	= 3,1 Mn	1	= 0,8 Mn
SiO^2	22		14		20	
Al^2O^3	1		2		1	
CaO	21		22		17	
MgO	30		38		30	
Loss on burning	5		0		10	
		16,2%		17,1%		15,5%

IODINE AND POTASSIUM CHLORIDE FROM METALLIC DUST FROM BLAST-FURNACES

By PETER DICKENS AND WALTHER MIDDEL. (From *Stahl und Eisen*, Vol. 62, No. 25, 18th June, 1942, pp. 518-525).

[Occurrence of Iodine in nature. Supply position in Germany. Description of a method to estimate iodine in metallic dust. Extraction and concentration of iodine. Composition of the mother liquor and the salts. Usual method of iodine extraction from waters containing small quantities of iodine. New method of obtaining iodine and potassium chloride from metallic dust].

IODINE in its compounds is found nearly everywhere in nature. But quantities are in most cases so small that extraction is not worth while. 75 to 80% of the world's iodine supply comes from South America. It is obtained from the mother liquor remaining after the refinery of raw potassium nitrate. On various places on the Scottish, English, French and Norwegian coast iodine is prepared from sea plants which contain from 0.01 to 0.08% iodine, but the methods are not economical.

In order to become independent from foreign countries with regard to iodine supply, various countries tried different methods with but little success.

War conditions, however, have drawn the attention to metallic dust from furnaces containing iodine, the quantities of which vary considerably with the origin of the coal and the ore. Quantities from 0.001 to 0.2% were found in metallic dust.

Estimation of Iodine in the Metallic Dust.

As the quantities of iodine in the metallic dust are only small and must, therefore, on economical grounds be easily obtained, only that part of the iodine which is soluble in water is of any interest for all practical purposes. This is why the method of estimating iodine in the metallic dust was only developed for the water-soluble part of the iodine content. At the same time it has been shown that by far the greatest part of the iodine contained in the metallic dust can be extracted by water. Thus a fusion process need not be carried out which has moreover, the disadvantage that through the considerable quantities of materials necessary for the fusion process iodine, contained as impurity in these materials is brought into the analysis process. There are other drawbacks, too, which might lead to faulty results, such as the danger that at high temperatures necessary for the fusion process alkali iodine may evaporate.

It was tried to apply the method by E. Wilke-Doerfurt (*Zeitschrift fuer angewandte Chemie*, 40 (1927) P. 1478/79) to the estimation of iodine in the metallic dust. The dry substance was treated with concentrated sulphuric acid in a specially designed distillation apparatus at 230° C. By this iodine and hydroiodic acid were set free, absorbed in a receiver and estimated. The experiment was first made with raw metallic dust, but the high carbonic acid content of the dust proved to be so great a disturbance when the substance was treated with the concentrated sulphuric acid that the process had to be repeated with that part of iodine only which is soluble in water. A series of tests was made in the following way: 100g metallic dust were boiled with 1000 cub. cm. water, the solution obtained after filtration was evaporated and the residue treated with concentrated sulphuric acid at 230° C. in the distillation apparatus. The substance absorbed in the receiver was oxidised with nitrosic sulphuric acid, iodine was extracted by carbon disulphide and titrated with sodium thio-sulphate.

Numerous experiments have shown that it is nearly always necessary to extract the iodine by an organic solvent after oxidation. As for the titration with sodium thiosulphate, it is important to note that owing to the presence of other anions in the solution the usage of sodium thiosulphate may vary considerably even up to plus or minus 100% in solutions containing equal amounts of iodine. Other mistakes may occur if titrations are carried out too quickly. As two layers are formed, sodium thiosulphate must be added gradually and the solution shaken frequently.

Another experiment was made where dilute sulphuric acid and a few drops of 10% potassium nitrate solution were added to the water extract of the metallic dust. The solution was then treated with carbon disulphide and the iodine containing carbon disulphide solution titrated with sodium thiosulphate. The normality of the sodium thiosulphate solution was determined by adding a potassium iodine solution of known iodine content to the mother liquor of the metallic dust remaining after extraction. The procedure described above was then repeated. The quantity of the potassium iodide solution added corresponded approximately to the iodine content of the liquor.

To test the reliability of this method titration was also carried out with arsenious acid. The water layer was separated, boiled and after acidification with nitric acid silver nitrate was added and the iodine determined gravimetrically in the usual way. Results were found to be the same as those arrived at by titration. The following procedure was adopted.

100g metallic dust were treated in a beaker with 1000 cub. cm. boiling water for an hour, stirring from time to time with a glass rod. The in water not soluble residue was filtrated and washed with hot water. The filtrate was evaporated to a volume of 150 cub. cm.

and sulphuric acid (1 + 2) was added until the solution showed distinctly acid reaction. After being heated to the boiling point, the liquid was filtrated into a graduated flask of 200 cub. cm. and left standing for an hour. If during this time the clear filtrate becomes milky, filtration has to be repeated. 100 cub. cm. of the clear filtrate were put in a Rothe extraction apparatus and a few drops of 10% potassium nitrite solution were added until the liquid showed brown colour when shaken. After 3 or 4 extractions, using 5 to 10 cub. cm. carbon disulphide each time, all the iodine was contained in the carbon disulphide which was now washed 3 times with about 10 cub. cm. water each time. The washing water was again treated with carbon disulphide which was then added to the main solution. The carbon disulphide was of red-violet colour and was titrated with 1/100 normal sodium thiosulphate solution until the colour disappeared. The normality of the sodium thiosulphate solution must be re-estimated each time.

It has sometimes been found that it was impossible to obtain a completely colourless solution after oxidation. But these iodine quantities remaining in the carbon disulphide are very small and may safely be disregarded.

Experiments to Extract and Concentrate the Iodine.

Owing to the fact that the iodine quantities in the metallic dust are very small it has become necessary to concentrate the iodine before transporting the materials in order to make the process economical. The high alkali content of the metallic dust led to the conclusion that iodine may occur in the dust as salt of sodium or of potassium, and it was therefore suggested that iodine could be extracted with water. Thus the two problems to be solved in the first instance were :

1. To find the economically most favourable conditions for the extraction and
2. To find the best method of concentrating iodine in the unit of volume without undue loss of iodine. A certain loss is, however, unavoidable.

1. *Variation of iodine solubility with temperature and duration of treatment.*

Various tests have shown that the solubility of the iodine increases as the temperature is raised and with the time the water is allowed to act upon the material. By prolonged treatment with boiling water practically 100% of the iodine can be extracted. It has further been found that at lower temperatures filtration became difficult and the potassium ferro-cyanide content of the solution decreased considerably. Hence the temperature at this stage of the process should not be allowed to fall below 50° C. The influence of the amount of water on the solubility of iodine will be dealt with at a later stage.

2. *Concentration of Iodine in the Mother Liquor.*

The experiment was carried out with 10kg metallic dust which was thoroughly boiled with 100 litres water and the liquid separated from the residue by filtration. The mother liquor was concentrated by evaporation to a volume of approximately 10 litres During this process 14.7 gramm of a mixture of salts separated out which were filtrated and analysed. The mixture was found to be composed of :

30.4%SiO_2, 6.0% Fe, 20.8% Al_2O_3, 1.1%CaO,
23.0% Na_2O + K_2O and 16.1% loss during fusion.

In the clear solution iodine was found to amount to 0.38 gramm per 1000 cub. cm. The process of concentration by evaporation was continued until at a boiling point of 106.5° C. and a volume of 3600 cub. cm. salts separated out in appreciable quantities. The solution was then cooled down and filtrated. 1300 gramm dry substance and 2165 cub. cm. mother liquor were obtained, the latter containing 1.5 gramm iodine per 1000 cub. cm. As the original iodine concentration was estimated to amount to 0.119 gramm iodine per 1000 cub. cm. 1.5 gramm iodine per 1000 cub. cm. represent an increase by 13 times of the original amount. The total loss on iodine during concentration process amounted to approximately 10% of the quantity originally contained in the metallic dust. Further concentration yielded the results as shown in Table I.

TABLE I.

Experiment No.	Boiling Point of the mother liquor (centigrade)	Obtained mother liquor (cub. cm.)	Lost mother liquor (cub. cm.)	Obtained Salt quantities (gramm)	Gramm. iodine per 1000 cub. cm. mother liquor	Iodine Loss %
1	110	2165	233.0	1300.0	1.50	10
2	112	72	19.2	69.7	1.50	21
3	114	60	18.8	73.8	1.90	24
4	117	47	19.0	79.0	2.30	29

The yield as obtained in experiment No. 1 can be regarded as satisfactory. It must, however, be noted that the iodine content as shown under experiments 2, 3 and 4 was calculated only and not determined analytically. The method described earlier could not be applied to the analysis of these concentrates, and it was assumed that considerable quantities of organic compounds with reducing properties were concentrated in the mother liquor together with the iodine. These organic compounds apparently counteracted the oxidation of the iodides. Even with carbon disulphide iodine could not be completely extracted.

Salts obtained during the Process of Iodine Concentration.

The experiments described above have shown that a considerable part of the metallic dust is soluble in water. Complete evaporation of the solution yielded amounts of dry substance (dried at 300° C.) ranging from 10 to 30% of the metallic dust. The 1300 gramm dry substance as obtained in experiment No. 1 (Table 1) was found to be composed of :

Cu....traces	Na....4.24%	CN.....nil
Mn....nil	K....42.48%	SO_4.....0.16%
Zn....nil	Al_2O_3..0.24%	[Fe $(CN)_6$]12.64%
Ca....0.06%	$Si0_2$...0.03%	$C0_3$.....2.72%
Mg....traces	C1....31.74%	H_20.....0.50%

It is interesting to note the high potassium content in this analysis. A relatively high potassium content was also found in the remaining mother liquor. The salts obtained in the experiment with the 10kg dust as described earlier correspond to an amount of 550 gramm potassium. These raw potassium salts can either be used directly as manure or can be purified and represent in either case a raw material of a certain value. Several experiments were made to determine the solubility of these salts. Table II shows the relation between yield, temperature and the time during which the solvent water was allowed to act upon the materials. Influence of temperature and duration of solution and quantity of water on solubility of salts.

Under all these conditions solubility may be regarded as satisfactory. The difficulties arising when filtration was carried out at low temperature were again experienced. The results obtained show that the valuable potassium salts may be extracted almost completely together with the iodine, a fact which makes the process more profitable.

Experiments to test the value of the raw salts as manure have shown that they acted favourably on the parts of the plants above surface, while damage to roots was observed. An explanation for this may be found in the high alkalinity of the salts and in their fluor content.

TABLE II.

Experiment No.	Temperature (centigrade)	Duration of solution (minutes)	Quantity of water used (cub. cm.)	Quantity of salts obtained (gramm)	Solubility %	Filtration
1	22	15	1000	28.5	87	bad
2	40	15	1000	29.5	90	fairly good
3	70	15	1000	29.7	91	good
4	100	15	1000	32.7	100	good
5	100	15	1000	32.7	—	good
6	100	30	1000	32.2	—	good
7	100	60	1000	31.5	—	good
8	100	180	1000	30.5	—	good
9	70	15	400	27.1	91	good
10	70	15	600	28.0	95	good
11	70	15	800	29.5	99	good
12	70	15	1000	29.6	100	good

Further Treatment of the Water Extract to obtain Iodine and Potassium Chloride.

By the experiments so far described the principal methods of obtaining an iodine containing mother liquor and raw salts have been established.

To obtain iodine from waters with very low iodine content 4 methods have been suggested.

(a) The silveriodide process.
(b) The starch process.
(c) The paraffin process.
(d) The activated charcoal process.

Of these (d) is by far the most important. This process which is being successfully used to-day can be divided into three stages, viz. :

(1) Pre-treatment of the iodine containing water.
(2) Absorption of the iodine by activated charcoal,
(3) Separation of iodine from the activated charcoal.

The pre-treatment comprises the pre-purification of the water and the oxidation of the iodides to obtain free iodine. The pre-purification must be carried out according to the impurities present, but care should be taken to eliminate organic compounds of high molecular weight as these would otherwise be taken up by the charcoal and thus reduce its absorptive capacity for iodine. After slight acidification iodine is set free through oxidation with potassium permanganate, chlorine or sodium nitrite.

The absorption of iodine by active charcoal may be carried out in various ways. For the technical process the direct method whereby the water is treated with pulverised active charcoal seems to be the most satisfactory method.

The separation of the iodine from the charcoal is best done by treatment of the iodine-charcoal with sodium carbonate or sodium hydroxide solution. The charcoal may, after preparation, be used again.

Experimental tests made with metallic dust extracts in accordance with the technical method just described have led to the assumption that certain substances must be present which caused serious disturbances. Other ways had therefore to be found.

To eliminate the influence of organic compounds the mother liquor was evaporated to dryness and by heating the dry residue it was tried to destroy the disturbing substances. The temperature was first kept low in order to avoid loss of iodine through evaporation, but as not much improvement was observed, the temperature was raised. After heating the residue for 30 minutes at about 600° C. the disturbing compounds were destroyed and the oxidation of the iodine could be carried out without hindrances. Losses of iodine were not observed.

The substance remaining after the heating was no longer completely soluble in water. A residue containing iron remained and the assumption that the potassium ferrocyanide was decomposed during the procedure was backed by the fact that this salt was not found in the new solution. These experiments not only indicated the way how to obtain iodine from the metallic dust, but made, at the same time, also the extraction of the potassium salts possible. It has been found in the course of further experiments that the fused residue is more readily soluble in water if the temperature is increased to 700° C. which may safely be done without risking iodine losses.

One shortcoming of this method is that the valuable potassium carbonate is lost owing to the fact that it is necessary to work in slightly acid medium. Thus the carbonate radical is exchanged against the radical of the acid in use. It is advantageous to use hydrochloric acid and ferrichloride as oxidising agent in order to obtain only one potassium salt, that is potassium chloride. By this method only ferrochloride and sodium chloride form the impurities of the potassium salt. The ferrochloride may be eliminated by means of strong hydrochloric acid or saturated potassium chloride solution, sodium chloride may be separated from the potassium salt through fractional crystallisation without difficulty.

Good results as to the purity of the potassium salt were obtained from a series of experiments. A certain amount of fluor, however, was always present, to an extent of about 2%, and ways and means had to be found to separate this impurity from the potassium salt. It seemed most suitable to effect precipitation of the fluor after the solution of the fused raw salts as filtration is necessary at this stage in any case to separate the iron oxide. Experiments were made with the chlorides of the alkaline earth metals (chlorides being used as other salts would bring undesirable anions into the process). It was important to find conditions where fluor is precipitated before a complete reaction between the potassium carbonate and the chloride of the alkaline earth metal had taken place. An excess of the latter had to be avoided as this would appear as impurity in the potassium chloride from which it would have to be separated.

During a series of experiments made with Magnesium, Barium, and calcium chloride respectively under varying conditions, the fluor content, on the one hand, and the alkaline earth metal content, on the other hand, were analytically determined after the filtration. Calcium chloride proved to be the most satisfactory reagent as it was possible to reduce the fluor content to 0.05% with only small quantities.

If fluor is separated by this method the technical process is not complicated to any appreciable extent, the calcium carbonate and the calcium fluoride being filtrated together with the iron-oxide. As the greater part of the potassium carbonate carbonic acid is linked to calcium and precipitated, only a small amount of hydrochloric acid is necessary to effect acidification. The cost of the calcium chloride is thus offset by the saving in hydrochloric acid.

The following final experiment was then made : 250 gramm raw salt was melted at about 700° C. and solved in water. After adding 35 gramm

Calcium chloride, the solution was filtrated and divided into 5 equal parts. Each part corresponding to 50 gramm raw salt was acidified with hydrochloric acid, oxidised with iron chloride and distilled in order to separate the iodine. Potassium hydroxide was added to the distillation residue until the mixture showed slightly alkaline reaction. The iron hydroxide was then filtrated and the clear solution neutralised with hydrochloric acid. The quantities of potassium chloride formed by the addition of hydrochloric acid and potassium hydroxide were precisely determined and taken into account when the final results were calculated.

The neutralised filtrates were evaporated, each to a different degree of concentration. The salts were filtrated and the dry substances obtained from the precipitate and the mother liquors respectively were analysed. The results are summarised in Table III.

the conditions for the technical application of the method were investigated.

Iodine occurs in the metallic dust in water-soluble form and can therefore be extracted by simple treatment with water under conditions which have been determined. By the treatment with water various other salts which amount to 10 to 30% of the metallic dust, are extracted together with the iodine. These salts consist chiefly of potassium and sodium chloride and potassium and sodium carbonate. There are also organic compounds contained in the water extract which make the separation of iodine according to the usual methods impossible and at the same time disturb the preparation of pure potassium salts considerably. It has been found that these organic compounds may be completely destroyed in the residue of the evaporated mother liquor at high temperatures. It was then

TABLE III

Experiment No.	Raw Salt used (gramms)	Gramms iodine per 100 g. raw salt	Yield Alkali-chlorides (gramms)	Crystallization						Mother liquor remaining					
				g Salt	K %	Na %	Cl %	F %	KCl %	g Salt	K %	Na %	Cl %	F %	KCl %
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	50	0.130	41.8	27.6	51.84	0.32	47.58	0.02	98.94	14.2	41.78	8.47	49.62	0.14	79.67
2	50	0.132	42.3	29.2	51.68	0.58	47.54	0.02	98.63	13.1	40.80	9.16	49.89	0.14	77.80
3	50	0.132	42.8	33.8	51.51	0.49	47.63	0.02	98.31	9.0	37.20	11.59	51.01	0.15	70.94
4	50	0.132	42.5	35.5	51.55	0.45	47.54	0.02	98.38	7.0	30.98	16.64	52.10	0.29	59.08
5	50	0.132	43.0	43.0	47.90	3.10	47.80	0.049	91.40	—	—	—	—	—	—

As it can be seen in column 3 the iodine quantities obtained by distillation are the same in each case. In column 4 the yields of dry substances are given which equal for each experiment the sum of columns 5 to 11 and average 85% of the raw salt. Column 5 shows the salt quantities obtained by crystallisation, which range from 55 to 71% of the raw salts, or from 66 to 84% of the total yield of salts (column 4). The potassium chloride content as shown in column 10 exceeds in 4 out of the 5 experiments 98%. Important is the low fluor content (0.02%) which has been reduced to one hundredth of the original quantity.

From the figures in Table III the conclusion may be drawn that, on the one hand, the potassium chloride obtained by crystallisation may be purified to a considerable degree by simple re-crystallisation and that, on the other hand, more potassium chloride may be extracted from the remaining filtrate.

A scheme of the methods applied and the amounts of iodine and potassium chloride obtained is shown at the end of this article.

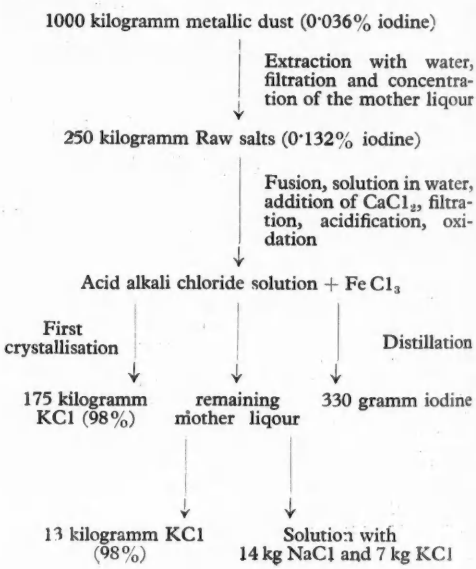
The following data may give the reader an idea of the quantities of iodine and potassium chloride that may be extracted from metallic dust. As example the Heinrich Bierweis Huette (Mannesmann Roehren Werke, Huckingen) may be taken, where approximately 17.5 tons metallic dust accumulate during 24 hours from which 4 to 5 kilogramm iodine and approximately 3 tons of 98% potassium chloride may be obtained.

As for the economical aspect investigations are still in progress. But that much is certain that in the case of iodine shortage the method discussed in the foregoing may be applied, having, moreover, the advantage of yielding potassium chloride as by-product.

Summary.

Metallic dust from furnaces contains small quantities of iodine and may, therefore, be used as raw material for iodine production. After the development of an analytical method to estimate the iodine content, possible to eliminate the fluor from the potassium salts by treatment with calcium chloride and to obtain 70% of the potassium salts originally contained in the metallic dust with a high degree of purity (98.5%).

The method by which metallic dust is treated with water, the mother liquor evaporated, the precipitated salt fused, the fluor eliminated, the iodine distilled and the potassium salt crystallised, makes it possible to make use of metallic dust hitherto considered as valueless waste product.


1000 kilogramm metallic dust (0·036% iodine)
Extraction with water, filtration and concentration of the mother liqour
250 kilogramm Raw salts (0·132% iodine)
Fusion, solution in water, addition of $CaCl_2$, filtration, acidification, oxidation
Acid alkali chloride solution + $FeCl_3$
First crystallisation
Distillation
175 kilogramm KCl (98%)
remaining mother liqour
330 gramm iodine
13 kilogramm KCl (98%)
Solution with 14 kg NaCl and 7 kg KCl

POWDER METALLURGY

I. PRODUCTION OF PRESSED STEEL COMPONENTS. RECENT DEVELOPMENTS AND APPLICATIONS.

(From *The Commonwealth Engineer*, Vol. 30, No. 1, August, 1942, pp. 3-6).

A MAIN advantage of powder metallurgy is that components of intricate shape can be formed directly to close tolerances without the necessity for machining. The cost of production may be less than with the older processes. The equipment required is simple and easy to operate. Powder metallurgy consists of: (1) Production of the metal powders. (2) Compacting of the powders under pressure into the required shape either at room pressure or at an elevated temperature and (3) sintering of the compact at an elevated temperature either in air or vacuum to form a rigid structure.

Many powders are being produced by grinding, pulverising and sintering. Generally only the more brittle metals can be reduced by these methods, but it may be possible to choose a composition that is brittle enough for pulverising and then to adjust the composition by adding virgin metal. Nickel iron alloys for magnetic materials are reduced by grinding in a ball mill after the grain size of the cast iron has been reduced and the metal fractured by repeated forgings at decreasing temperatures.

Of the three electrolytic methods for the production of metal powders the most effective is the deposition of the metal in a short spongy condition, the deposit being rubbed lightly into a powder. The powder can also be deposited as such directly by the electrolytic method. Copper powders are produced most effectively by this method. The best conditions involve the use of high current densities, the powder being removed by a scraper from the slowly rotating cathode.

With regard to deposition from a gas the only powders that can be produced successfully by this method are those of iron and nickel and their alloys, the powders being produced by the reduction of their respective carbonyls at high temperatures and under high pressure. The metal precipitates as a powder which can be ground in a ball mill to reduce the particle size still further.

The method of chemical reduction is the most commonly used, as for example in the production of powders for cutting tools the oxides of tungsten, etc., are reduced at high temperatures in a hydrogen atmosphere, the resulting powder being that of the pure metal. Metal powders can also be produced by atomisation, that is, the dispersion of a molten metal by a blast of air, the small particles solidifying on cooling; aluminium, lead and tin powders have been produced by this method. Zinc powder suitable for sintering is obtained by direct distillation and condensation.

The particle size is governed by experience and depends on the purpose of the compact and the nature of the powder. The measurement of the particle size is by screening or by elutriation, the former being more common as powders of less size than 400 mesh are seldom required. Powders can be compressed to a higher degree at elevated temperatures and particles more heavily deformed with a consequent reduction of porosity and less sinkage.

Up to a limit the higher the temperature at which sintering is done the greater the strength obtained while the time necessary depends on the powder. The furnace temperature must be uniform, it must be thermostatically controlled and cooling must be slow. Shrinkage is greater for fine powder compacts and, because of the deleterious effect of the formation of oxides on the physical properties of the compact, a vacuum furnace of the high frequency induction type may be used, the furnace being evacuated continuously during the process.

Alloying results from the diffusion of one metal into another. With regard to heat treatment spontaneous grain growth occurs at a certain temperature which can be reduced by cold working the compact. To produce components having high physical properties from iron powder, the compact is pressed cold and sintered at 1025° C followed immediately by hot pressing. The compact is then quenched, annealed and pressed cold in another die.

Porous bearings which are replacing phosphor bronze are made of compacts of 88 per cent copper, 9 per cent tin and 2 per cent graphite. The average properties produced are 8 tons per square inch tensile strength, 30 tons per square inch compressive strength and 6.5 specific gravity. The material is soaked in oil and absorbs about 25 per cent by volume. This oil content is a permanent lubricant. Small gears can be produced at about 100 per minute in automatic presses from iron and steel powders, these being decarbonised before briquetting and the powders being produced by ball milling to about 300 mesh. Steel dies are used for compacting pressures varying up to 25 tons per sq. in. while sintering temperatures are up to 1100° C the furnace atmosphere being usually hydrogen to prevent the formation of oxides.

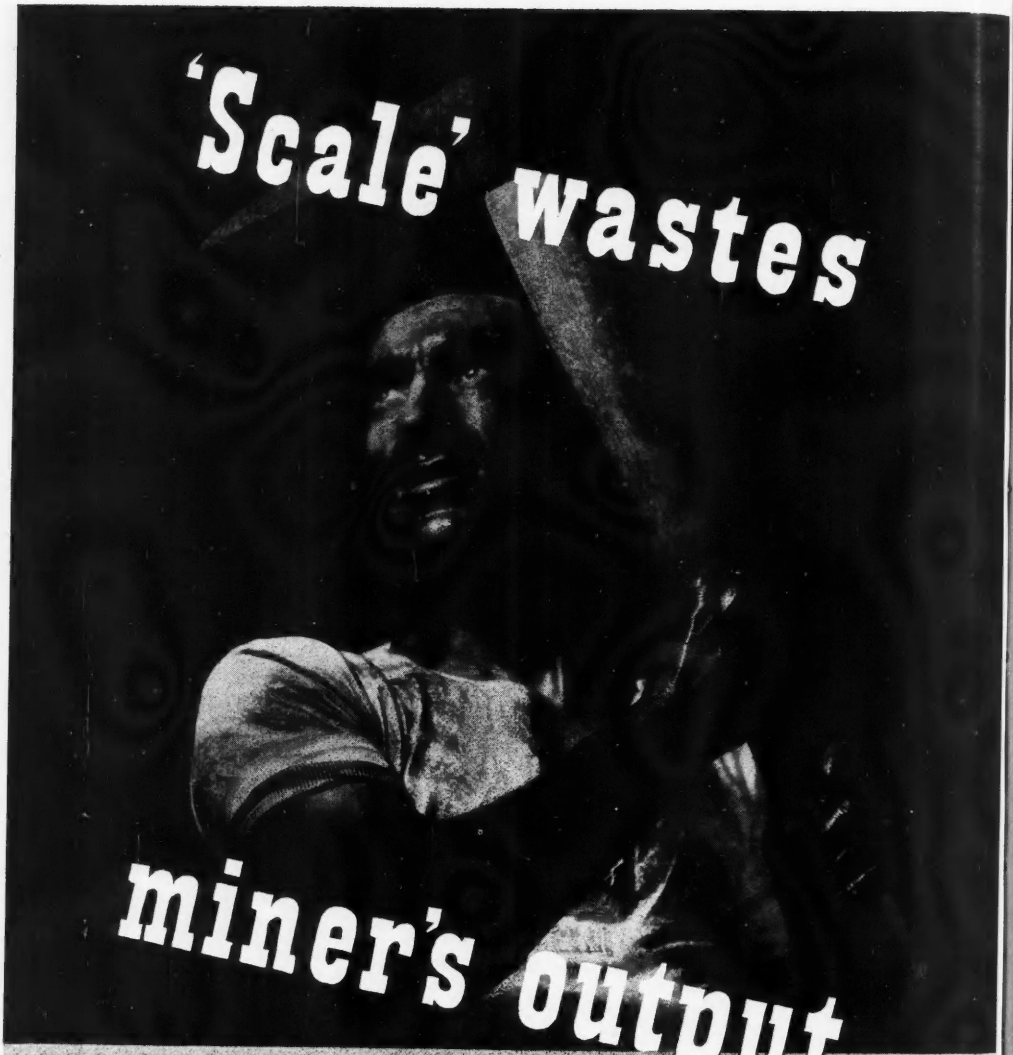
An early application of powder metallurgy was the production of carbide tips for tools made from tungsten-carbide-tantalum carbide, tungsten-carbide-cobalt, and titanium-copper-nickel. Electrical contacts are made of tungsten-copper, tungsten-silver and tungsten-copper nickel. For brake and clutch linings a copper base is used to which is added lead, tin, iron, graphite and silica powders. The powders are mixed and pressed cold under a pressure of 11 tons per sq. in. to the required shape, then sintered and at the same time bonded to the steel backing at a temperature between 750° C and 900° C under pressure and in an atmosphere of hydrogen.

II. POWDER METALLURGY.

By F. C. KELLEY. (From *Electrical Engineering*, Vol. 61, No. 9, September, 1942, pp. 468-475).

POWDERS when pressed do not flow around corners, therefore the plungers must operate in straight lines. Automatic machines turn out small parts and, as size increases, so does the cost. With increase in size also there is no uniform distribution of pressure throughout the compact, which results in uneven shrinkage if the sintering temperature is sufficiently high and if low the density is not uniform. In experiments the strength of a gear tooth under static and dynamic loading was determined by clamping the gear so that a vertical load could be placed on the tooth tangential to the gear periphery thus loading the tooth in shear, with the effective area that of the root of the tooth. The breaking load was 1400 lbs., the equivalent of 10,380 lbs. per sq. inch. For the impact loading a 1 lb. weight was used and the tooth broke when the weight was dropped from 10 ins. Since the area of the tooth was 0.135 sq. in. the weight required to break the tooth was equivalent to 6.2 foot-pounds per sq. in.

(*To be continued*)



The Ministry of Fuel & Power's urgent call to save coal is a direct appeal to engineers all over the country. 'Scale' has long been recognised as a menace in industry. It is responsible for lining tubes and boilers with heat-resisting deposit that causes considerable heat loss and over-heating of metal. As the Ministry have pointed out in a recent broadcast . . . "1/16th of an inch of scale can result in as much as a 6% loss of efficiency." Thousands of tons of fuel are wasted annually in fighting 'scale' in order to bring boilers up to maximum efficiency, to say nothing of the danger of stoppages whilst the damage is being repaired. It is a national service to eliminate 'scale.' For the presence of 'scale' blame your feed water supply. The Permutit Water Softening Processes are adaptable to any industry, and are the complete solution to this vital problem. *Write* Permutit Company Ltd., Dept. T. B., Gunnersbury Ave., Chiswick, London, W.4, for full details.

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

CATALOGUES RECEIVED.

Metal Finishes.—The surface treatment of ferrous and non-ferrous metals and alloys is very complex, and Metal Processes Ltd., 48, Frederick Street, Birmingham, are to be congratulated on the preparation of a booklet in several colours giving practical information on black and coloured finishes on iron, steel, and various non-ferrous metals and alloys. Degreasing and Rust preventing are also considered in this publication. The information given is terse and clear, and firms are invited to send self colour samples of their products to be treated without charge. Illustrations of plant and equipment necessary for the various processes are included in the brochure.

Drilling and Milling Machines.—It is an achievement for Adcock and Shipley, Ltd., Ash Street, Leicester, to have produced two comprehensive illustrated catalogues at the present time, one dealing with Drilling machines and the other with Milling machines operating at speeds up to 4,000 r.p.m. Tooling equipment and what may be classed, broadly, as accessories are also described. The range of machines is extensive, and the catalogues should prove as useful as they are interesting.

PERSONAL.

Mr. Arthur E. Hagg has joined Airspeed (1934) Ltd., an associate company of De Havilland as technical director and director of design.

Mr. W. L. Morse, B.Sc. (Eng.), A.M.I.Mech.E., has joined the Aircraft Section of Messrs. Alan Muntz & Co. Ltd., Heston Airport, as chief technician.

Mr. J. T. Ewen, O.B.E., B.Sc., M.I.Mech.E., who took part, when employed with Sir Wm. Arrol & Co., Ltd., Glasgow, in the erection of the Forth Bridge, has died recently.

EDITORIAL INDEX AND BINDING CASES.

The Editorial Index to Vol. III, 1942, of our journal will be sent to all Subscribers free of charge upon application.

Binding Cases for the binding of Vol. III. of THE ENGINEERS' DIGEST are now available. The price is 4/6 including postage.

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BOOKS RECEIVED.

Boiler Plant Technology.—By R. L. Batley and E. Gordon Barber, Sir Isaac Pitman & Sons, London. 284 pp., 5 × 7½ in., cloth, price 15/-. This book is especially topical owing to the present importance of increased fuel economy. It should be made available to all boiler plant operators as the thorough understanding of chemical problems and of operating technique which can be gained by reading this book would stimulate the obtaining of maximum operating efficiency in boiler plants under their control.

Studies in Political Science and Sociology.—University of Pennsylvania Press (for Great Britain: Sir Humphrey Milford). 6 × 9 in., 194 pp., cloth, English price 10/6.

The Problem of Unemployment. — Lever Brothers and Unilever Ltd., Unilever House, Blackfriars, London, E.C.4., has published this paper of 40 pages suggesting the regulation of the productive activity of the nation to meet the requirements of labour and industry. The paper is a most valuable contribution to the present discussions in connection with the economic covenants of the Atlantic Charter and with the Beveridge Report. A limited number of copies may be had upon application to the Secretary of Messrs. Lever Brothers.

CORRECTIONS.

Rectangular Plates under UniformlyDistributed Fluid Pressure.—On p. 377 of our November issue the diagram Fig. 1 is printed upside down. The first line on the same page should read :

$$\text{Deflection at point m: } f = n_1 a \sqrt[3]{\frac{pa}{E_s}}$$

Drag Problems in Present Day Aircraft Design.—On p. 427, second column, 4th line, substitute reduced for reached.

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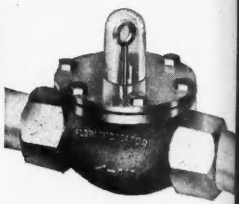

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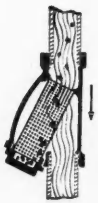

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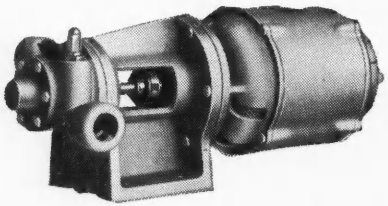

Specifically designed for dealing with oils of high viscosity. Their reliability, robustness and versatility make Varley V.O. Pumps particularly useful for supplying oil to machine tools at low or high pressure, for transfer work and hydraulic applications.

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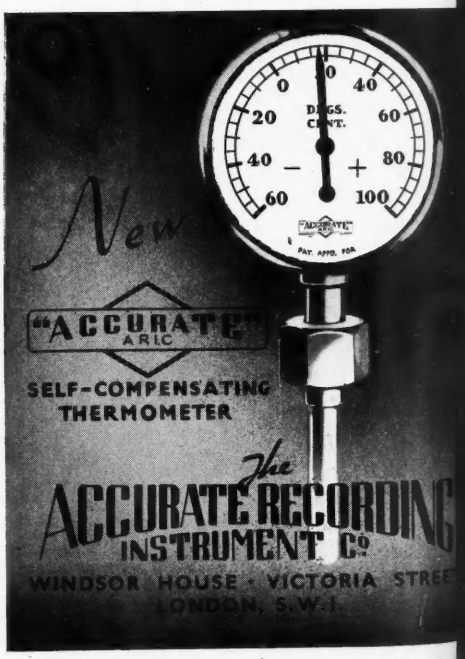
V.2.